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WADC TECHNICAL REPORT 52-179

SECURITY INFORMATION

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Date: 30 July 1952

ANTIJAMMING PERFORMANCE OF RADAR SET AN/APS-23(XA-2)

(Tunable Radar System)

GEORGE S. MILLER
AIRCRAFT RADIATION LABORATORY

APRIL 1952

WRIGHT AIR DEVELOPMENT CENTER

52WC-26679

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WADC TECHNICAL REPORT 52-179

SECURITY INFORMATION

ANTIJAMMING PERFORMANCE OF A RADAR SET AN/APS-23(XA-2)

(Tunable Radar System)

George S. Miller
Aircraft Radiation Laboratory

RDO No. 112-40

April 1952

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

52WC-26679

CONFIDENTIAL

FOREWORD

WADC Technical Report 52-179 was prepared by Mr. G.S. Miller of Aircraft Radiation Laboratory, Directorate of Laboratories, WADC. The work was conducted under Research and Development Order No. 112-40, "Techniques, Antijamming, for Airborne Radar." The author of the report is the Project Engineer.

The pilot and crew of the B-50 aircraft and the AN/APS-23(XA-2) radar operator, all from the Air Force Armament Center, Eglin Air Force Base, Florida, made the flights and operated the radar during the tests.

The Countermeasures Branch and Electronic Warfare Center at Evans Signal Laboratory of the Signal Corps operated the ground-based jammer and automatic-tracking radar equipment used in conducting the antijamming flight tests.

The Armament Laboratory of the Directorate of Laboratories, WADC, cooperated on the project by assigning a B-50 aircraft equipped with a standard installation of Radar Set AN/APQ-24 to the project, thereby simplifying the installation of the tunable AN/APS-23(XA-2) radar system in the aircraft. The utilization of power supply, indicators, antenna radome, and mounting brackets of the AN/APQ-24 installation greatly expedited the work in making the AN/APS-23(XA-2) installation.

The author desires to express his appreciation to:

Mr. Robert Browning of Western Electric Company, who supervised the installation of the AN/APS-23(XA-2) in the aircraft and whose close coordination throughout the whole project greatly contributed to its success.

Captain R.M. Quimby and Mr. P.W. Miller of the Air Force Armament Center, Eglin Air Force Base, whose direct supervision and participation in the operation of the AN/APS-23(XA-2) during the flight tests produced flight evaluation data for this report.

Mr. Fred McCall and Mr. George Hogelin of Evans Signal Laboratory, Belmar, New Jersey, whose operation of the AN/TPQ-8 ground-based jammer, often under very adverse weather conditions, materially contributed to the success of the project.

Lt Bennett and his crew of radar operators of the Electronic Warfare Center, Evans Signal Laboratory, who operated the SCR-584 radars which directed the AN/TPQ-8 to the aircraft during the antijamming flight tests.

Mr. H.D. Vanderpool of Aircraft Radiation Laboratory, who conducted sensitivity and power measurements on the AN/APS-23(XA-2) radar system after it was installed in the B-50 aircraft and also coordinated in the work of installing the radar system in the aircraft.

Mr. Homer P. Stenersen of Aircraft Radiation Laboratory, who coordinated the installation of the camera recording device on the Radar Set AN/APS-23(XA-2).

ABSTRACT

The results of the tests performed in determining the antijamming performance of the AN/APS-23(XA-2) tunable bombing radar system are described. The analysis of the antijamming performance of the Radar Set AN/APS-23(XA-2) was made in the Aircraft Radiation Laboratory of the Directorate of Laboratories, Wright Air Development Center. The antijamming evaluation flight tests were made in the vicinity of Asbury Park and Atlantic City, New Jersey. The testing and evaluation described in the report was performed jointly by personnel from Aircraft Radiation Laboratory and Armament Laboratory of WADC, and the Air Force Armament Center, Eglin Air Force Base, Florida.

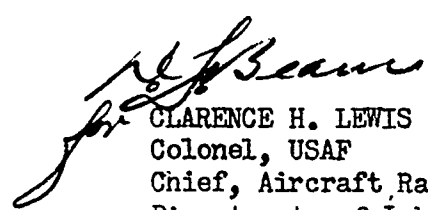
It is concluded that: (1) The AN/APS-23(XA-2) radar operator can make bombing runs using the APA-44 computer with the subject radar system without being effectively jammed by Radar Set AN/TPQ-8, noise-modulated ground-based centimetric-wave jammer. During flight tests where the radar operator was using maximum evasive operating techniques, the AN/TPQ-8 was only able to produce effective jamming of the radar for periods of two seconds during a simulated bomb run of 44 miles; (2) By tuning the AN/APS-23(XA-2) away ±25 mcs (or more) of the mid-point of the jammer frequency, the radar operator can completely free his screen of jamming. This tuning is accomplished by push button control at the operating position. All statements in this report relative to jamming refer to jamming signals from the AN/TPQ-8 equipment. This is the latest type, high-power, centimetric-wave, directive, ground-based, tunable jammer available from any of the Armed Services.

The security classification of the title of this report is SECRET.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:



CLARENCE H. LEWIS
Colonel, USAF
Chief, Aircraft Radiation Laboratory
Directorate of Laboratories

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INTRODUCTION

A study of the problems involved in the possible development of a tunable radar system was first contemplated in the latter part of 1944 after tests conducted at Lake Okeechobee in Florida indicated that part of the radar presentation on an airborne radar system (SCR-717) could be obscured by a ground-based jammer having a power output of less than 50 watts.

Since antijamming circuitry of the more conventional types seemed to have serious limitations and in many cases impaired the quality of the radar picture and the over-all sensitivity of the system, the possibility of tuning away from the jammer frequency appeared to offer a logical solution. As a result, a tunable system was evolved on paper and became the subject of a patent disclosure in January 1945 under the title "A Variable Frequency Radar System." This disclosure was subsequently divided into three patent applications, one under the title "Radio Object Locating System, Variable Frequency" and two others under the title "Rapidly Tunable Magnetron." Patents were granted on these applications and have been assigned serial numbers 743, 904, and 478, respectively. These are presently carried in a SECRET security classification and were assigned to the Air Force by Mr. R. F. Rychlik of Aircraft Radiation Laboratory.

The first of these patents deals with the design of a system in which the frequency may be changed from one value to another either by manual control at the will of the operator, as in the XA-2 system, or continuously by means of a motor-driven tuning device, as desired. In the latter case the radar would, therefore, transmit successive pulses on different frequencies, and provision is made for momentary blanking of radar presentation wherever the radar frequency crossed a jammed channel. In the XA-2 system the objective was set at acquisition of a radar set which could be reset in frequency by remote control without necessarily being operative during the tuning process, the latter being considered as being an excessively stringent specification and beyond foreseeable requirements for some time to come. However, a system of that type is now in the research stage under contract with the General Electric Company.

Existing radio-frequency components for radar were not suitable to the construction of a synchronized remotely tunable system at the time of its conception. Hence, a letter dated 24 May 1946 was addressed to the Electron Tube Branch at Air Materiel Command from Aircraft Radiation Laboratory requesting the development of suitable components. Since the Signal Corps had cognizance of all electron tube development at that time, the matter was referred through channels to Hq, Signal Corps, for allotment of funds, and development of components was initiated.

In the meantime, a tentative specification for an airborne variable-frequency radar system was made the subject of an Air Force Technical Note No. TN-TSERR2D-6 dated 10 September 1945 and titled "A Proposed Radar System Characterized by Low Vulnerability to Jamming." This was presented at an Armed Services - Manufacturers Conference held at Watson Laboratories in August of 1946 with the object of obtaining proposals for the construction of the system by contract. However, since design of new magnetron and oscillator components was involved, the two proposals received were too nebulous and high-priced to merit any serious consideration with available funds. Hence, it was decided to postpone further action on a complete system until Signal Corps could, through its function as the procurement agency for such components, provide the necessary magnetron and local oscillator.

In the meantime, the directive type ground jammer which evolved into the present Radar Set AN/TPQ-8, specifically designed for countermeasure work against airborne bombing radar, was being perfected. In 1949 the prototype of this jammer was tested at W-P AFB against the AN/APQ-13 radar system in the Project Bendix tests and proved so effective that Hq, Strategic Air Command, whose aircraft had participated in these tests, were impressed with the urgent need for positive antijamming protection for bombing radar.

Consequently, Aircraft Radiation Laboratory received a letter from Hq, USAF, Directorate of Research and Development, dated 19 January 1950 in which authorization was granted to pursue on high priority the development of a jam-proof airborne bombing radar system for use at the Strategic Air Command. Since the necessary components were available by that time, and had been successfully embodied in the T-33 anti-aircraft control radar system, it remained to redesign some existing airborne radar to accommodate the tunable radio-frequency components.

After careful study it was decided that a tunable version of the AN/APS-23 airborne bombing radar system could be developed. A contract was negotiated in June 1950 with the Western Electric Company for the modification of that radar which resulted in the AN/APS-23(XA-2) tunable radar set, the antijamming performance of which is the subject of this report.

SECTION I

DETAILED DESCRIPTION OF THE EVALUATION WORK

PURPOSE

The purpose of the work described in this report was to evaluate the antijamming performance of the centimetric-wave, tunable, airborne bombing radar system AN/APS-23(XA-2). The problems presented in conducting the tests described in this report were essentially those of performing laboratory studies, flight tests and analyses.

APPROACH

The AN/APS-23(XA-2) was set up in the Antijamming Research Unit of the Aircraft Radiation Laboratory at Wright-Patterson Air Force Base for the initial phase of the antijamming evaluation. After laboratory studies were made the radar system was installed in a B-50 aircraft and shakedown flights were flown in the area of Wright-Patterson Air Force Base to insure that the system was operating according to specifications. Upon completion of the shakedown tests the AN/APS-23(XA-2) was flight tested in a series of A-J test runs while operating against a ground-based AN/TPQ-8 centimetric-wave jammer in the vicinity of Belmar, New Jersey.

FACTUAL DATA

When the AN/APS-23(XA-2) was received from the contractor, it was installed in the laboratory of the Antijamming Research Unit, with the antenna of the radar mounted on the roof of the laboratory building. In a line-of-sight position at a range of approximately one-quarter mile, an experimental centimetric-wave, noise-modulated jammer was beamed into the antenna of the AN/APS-23(XA-2).

Antijamming studies were made on the radar set while it was being subjected to high level directive jamming at close range. This test was conducted principally to enable personnel to become familiar with the equipment, to study the effect of strong jamming on the radar selectivity, and to facilitate the development of a data recording device being developed by the Antijamming Research Unit. In this test it was determined that the radar was functioning according to specifications and that by tuning the radar approximately 20 mcs from the midpoint of the jamming frequency the radar operator could clear the indicator of jamming signals. Final adjustment, tune-up and checking of the AFC section were performed and a meter was installed in the camera to indicate the received jamming power at the second detector of the radar receiver.

No attempt was made at this stage of the antijamming evaluation to conduct tests involving tuning of the jammer or evasive tactics by the radar operator.

Upon completion of this initial phase of work on the AN/APS-23(XA-2), the radar set was installed in the forward pressurized station of a B-50 aircraft. Figure 1 shows aircraft #48056 in which the installation was made. Figures 2 thru 7 show the radar installation inside the aircraft. Each picture identifies a section or units of the installation.

By utilizing common parts of the AN/APS-23(XA-2) and the AN/APQ-24, such as power supplies, radome and indicator, the normal installation time of approximately five weeks was reduced to five days.

Upon completion of the installation of the AN/APS-23(XA-2) in the aircraft, the aircraft was flown in the vicinity of W-P AFB in order to determine that the radar was operating according to specifications. Two of these shakedown flights were made. It was found that the radar was functioning according to specifications and the aircraft was flown to Eglin Air Force Base, Florida, where resolution tests were made on this radar system. These tests are described in WADC Technical Report No. 52-157.

After a study of the problem, it was determined that the best field method for making an antijamming evaluation of the AN/APS-23(XA-2) tunable radar set would be to subject the radar system to jamming from the AN/TPQ-8 noise modulated, ground-based tunable jammer. A series of flight test runs were planned wherein the AN/APS-23(XA-2) operator could bring into use operating and flight procedures such that they would enable an antijamming evaluation of the radar to be made. The AN/TPQ-8 is a representative ground-based type of high-power, centimetric-wave jammer readily available at present.

At this point a brief description of the AN/TPQ-8 and the AN/APS-23(XA-2) is given in order that a better understanding may be had of the details of the flight tests that are about to be described.

DESCRIPTION OF RADAR SETS AN/TPQ-8 AND AN/APS-23(XA-2)

The Radar Set AN/TPQ-8 is a ground-based intercept and jamming equipment specifically designed as a countermeasure against airborne blind bombing radar and guided missile systems operating in the centimetric-wave region. The receiving components consisting of antenna system, receiver, and panoramic display unit cover the frequency range of 8,000 to 12,000 megacycles. Receiving system sensitivity is nominally 82 dbm. The transmitting components consisting of antenna system, RF unit, noise modulator and high voltage rectifier cover the frequency range of 8,500 to 10,000 megacycles. The equipment has been designed for a maximum power output of 1.5 KW, noise modulated; however, presently available tubes limit the nominal power output to a maximum of 800 watts with a tuning range of 600 megacycles about the center frequency of 9375 megacycles. Plug-in provision exists for pulse or sine-wave modulation by external modulators. The equipment provides continuous look-through operation if used in pairs; ie., one for jamming, and one about 100 ft away for receiving and monitoring, both being directed by the same radar system.

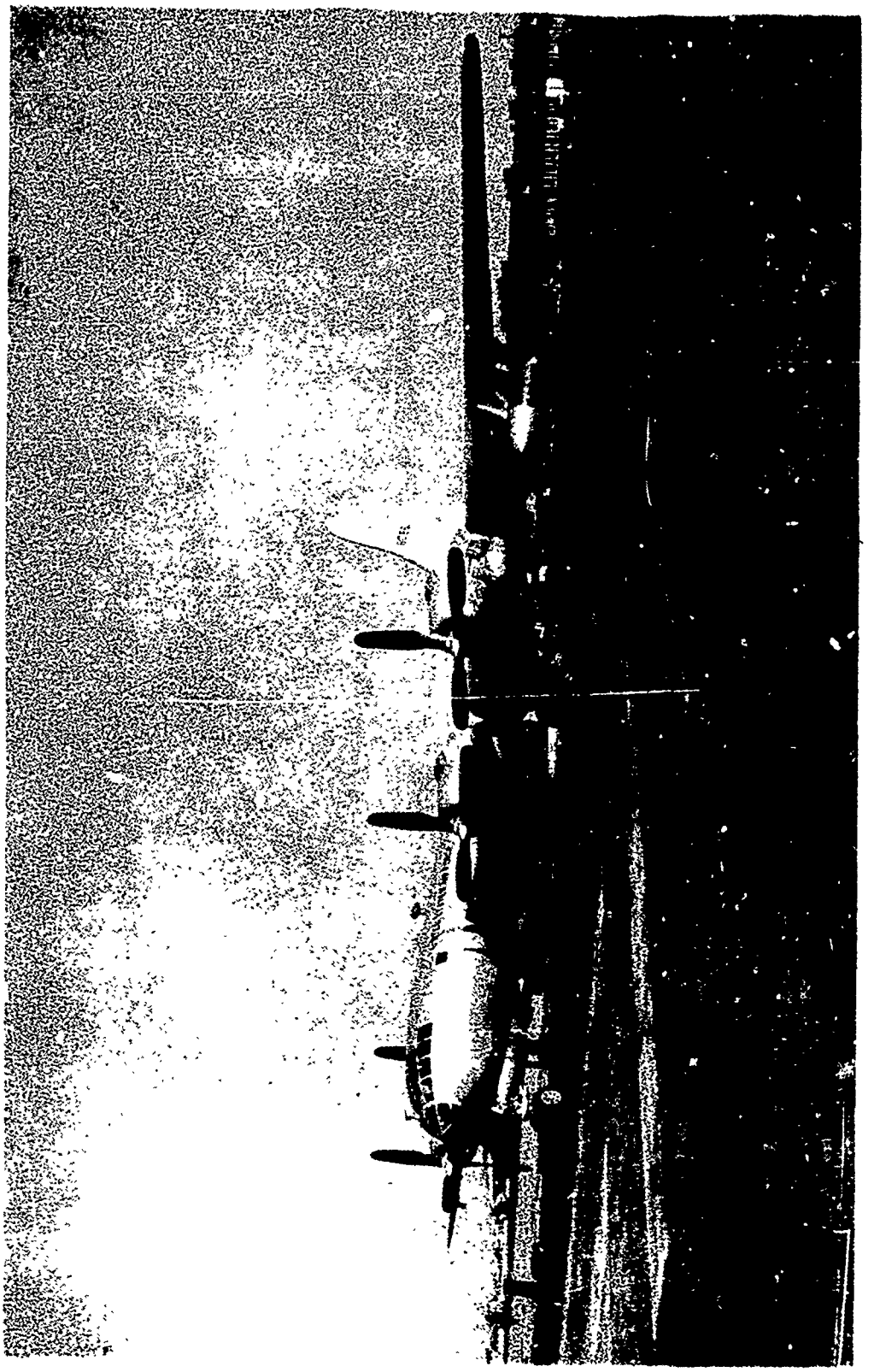


FIGURE 1. Aircraft B-50 No. 48056
The AN/APS-23(XA-2) was installed and flight tested in this aircraft.

FIGURE 2. Antenna Radome of AN/APS-23(XA-2) as Installed in Aircraft B-50 No. 48056

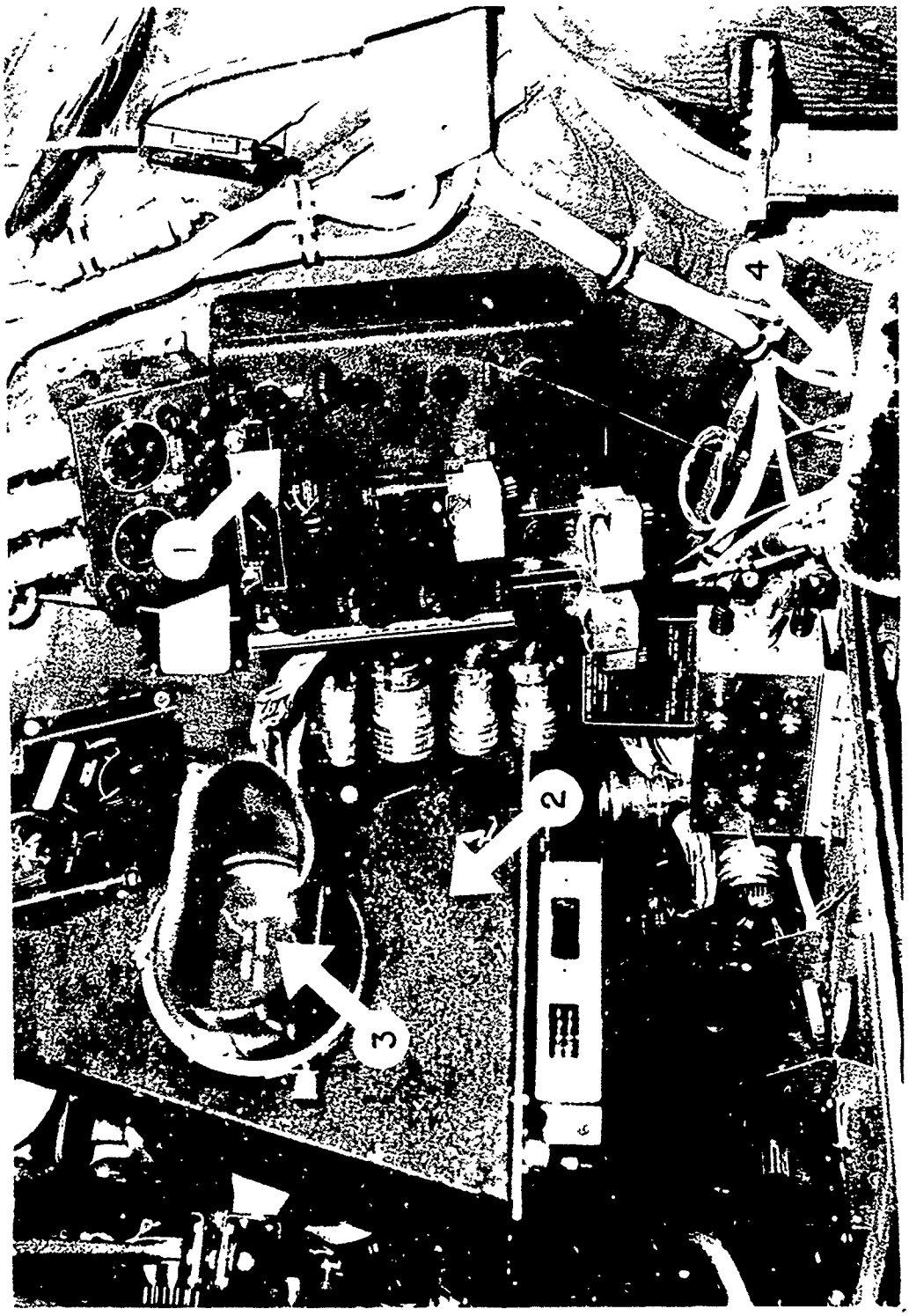


FIGURE 3. Front View of Data Recording Device and Radar Control Unit Installed in B-50

Installation in forward pressurized section of B-50-48056 showing AN/APS-23(XA-2) control box and data recording device in place over the indicator unit.

1. Control Box
2. Data Recording Device
3. Indicator Unit
4. Operator's Position

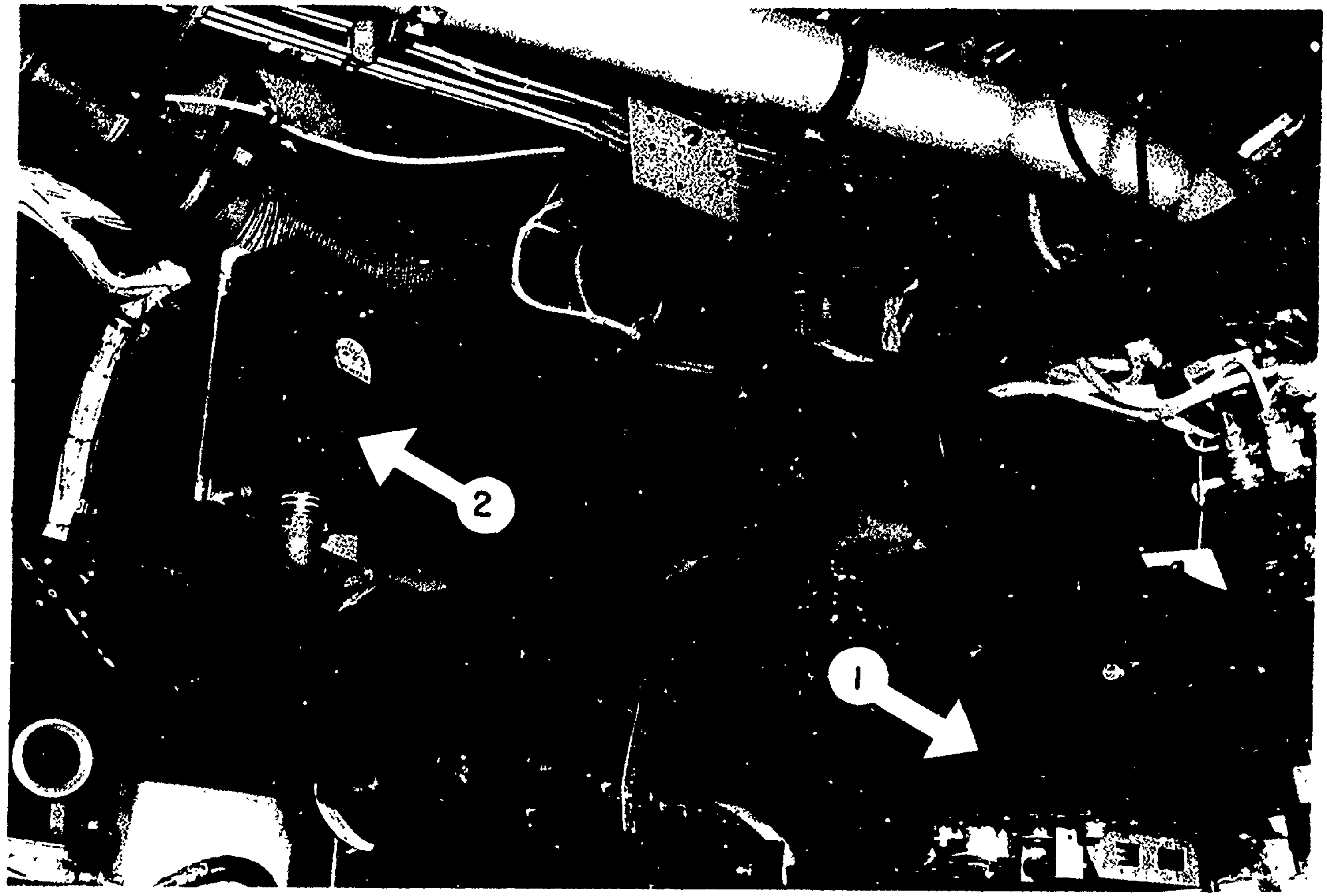


FIGURE 4. Tuning Control Unit Installed in B-50

Installation in forward pressurized section of B-50-48056 showing data recording device in place over the indicator and the push button frequency tuning control box with frequency indicating meter.

1. Data Recording Device
2. Tuning Control Unit

FIGURE 5. Position of Auxiliary Indicator Installed in Forward Pressurized Section of B-50 No. 48056

1. Auxiliary Indicator Unit

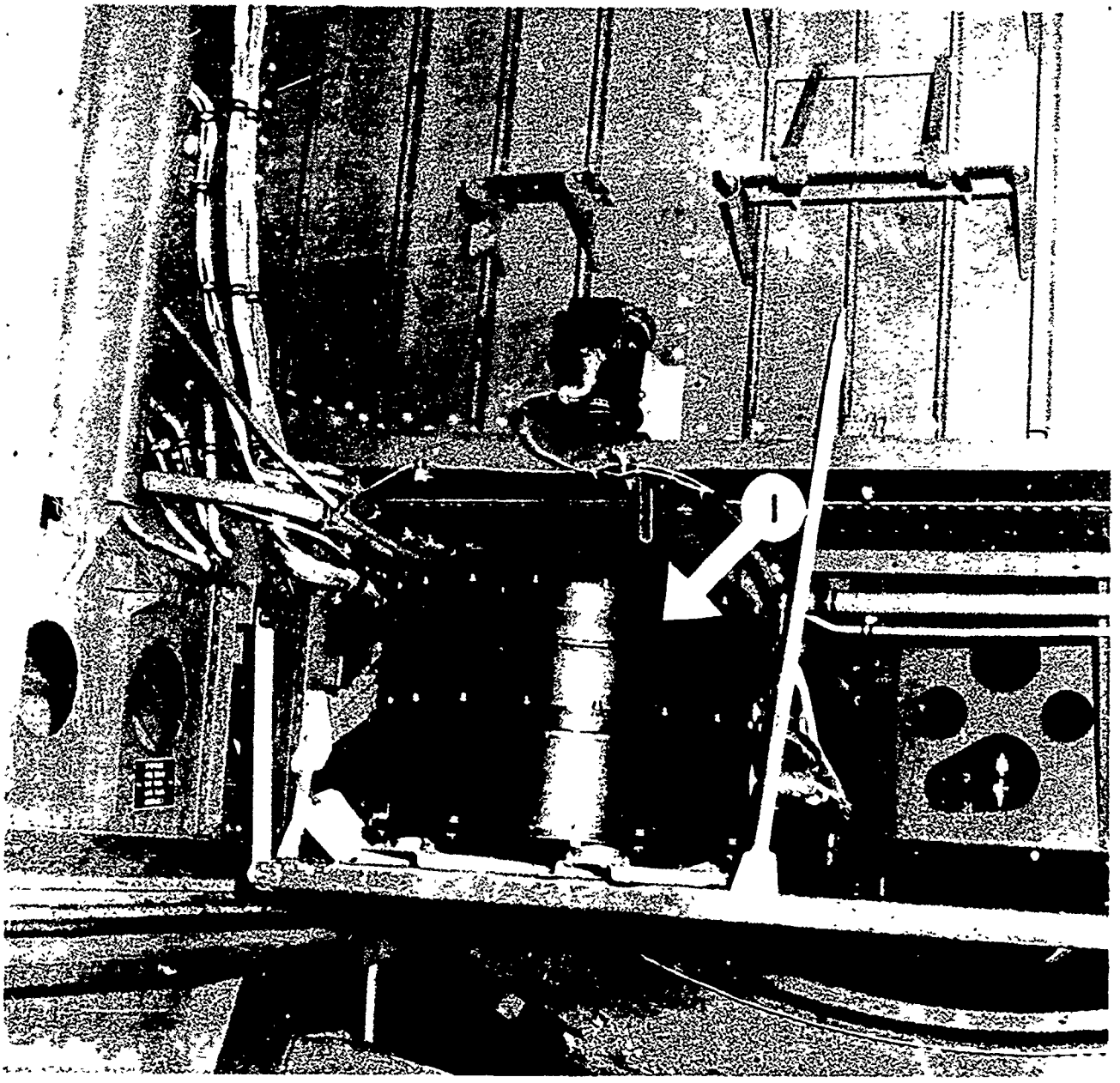


FIGURE 6. Installation of Radio Frequency Unit in the Bomb Bay of B-50 No. 48056

1. RF Unit

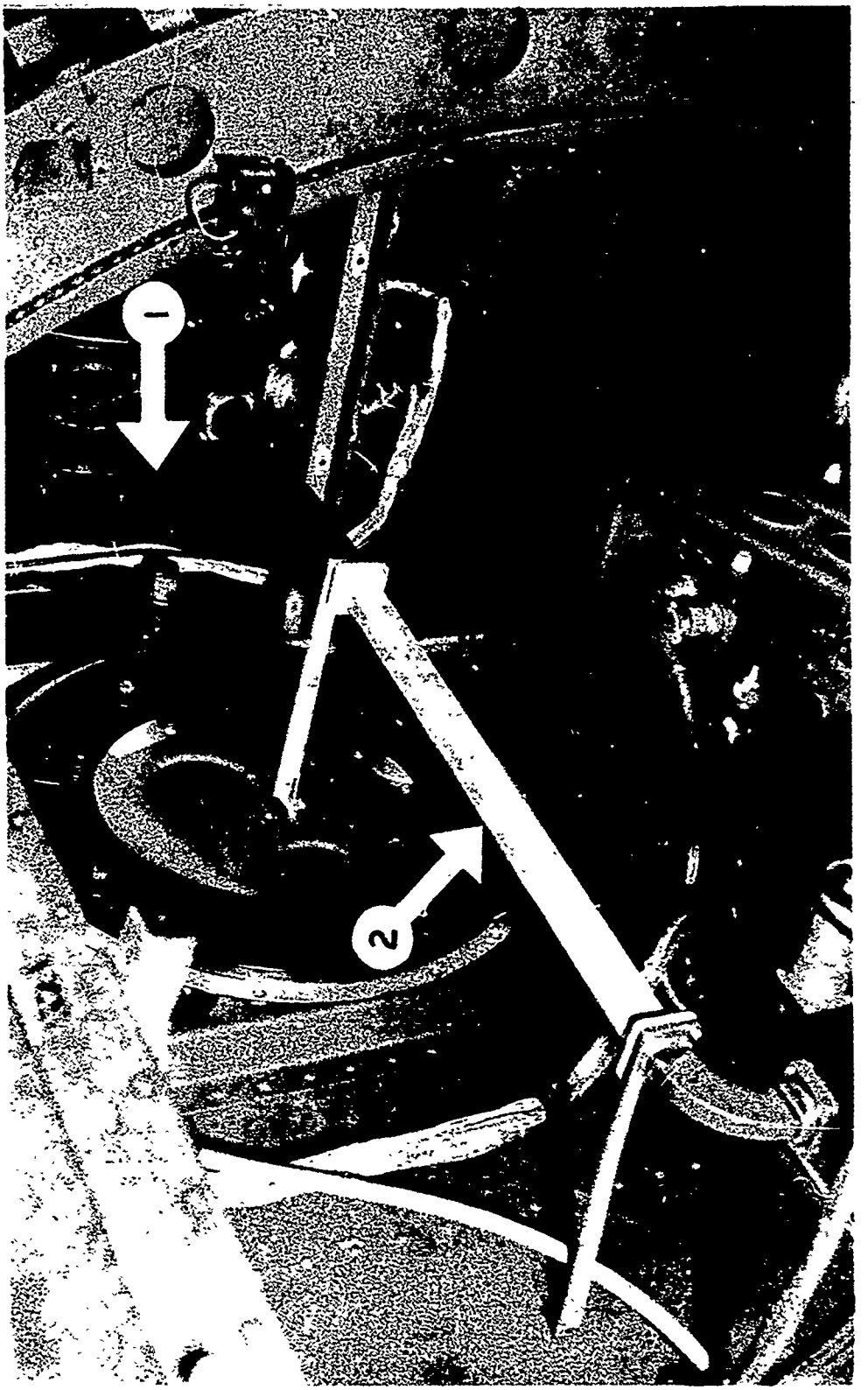


FIGURE 7. Installation of RF Head and Waveguide Assembly in the Bomb Bay of B-50 No. 48056

1. RF Head
2. Waveguide Assembly

The AN/TPQ-8 is designed to accomplish the intercept function when operating on a passive intercept and D/F set. The equipment is capable of tracking targets by manual operator control and can be made to transmit directional data to a control central or tracking radar. Employment of several sets on a known baseline will provide D/F positioning data. Transmission of video data is also possible. When operating as a jammer, provision is made for slaved operation with a tracking radar (a modified SCR-584 to give extended range was used in these tests) or for independent operation as intercept and jamming equipment utilizing the continuous look-through provisions and an independent method of tracking with manual or aided tracking azimuth and elevation control.

Other technical characteristics of the AN/TPQ-8 are shown as follows:

Power Output	600-1500 watts
Modulation	Internal noise, external pulse, or other
Methods of Operation	Local-manually operated passive tracking system. Remote-automatic tracking on angular radar data
Antenna Beamwidth	Receiver -5° conical. Transmitter-narrow, 4° az, 2-1/2 el, wide, 7° az, 2-1/2 el.
Antenna Polarization	Variable in stops at 45°, 90°, 135° and 180° horizontal
Outgoing Data	1:1 speed - azimuth and elevation - coaxial video data - synchronized scanning data
Incoming Data	1:1 speed - azimuth and elevation
Transportation	Mounted on four wheels for emplacement. A searchlight trailer must be used for long hauls
Operators	One tracking and one frequency scanning. Additional operators necessary for tracking radar, etc.
Weight	4000 pounds
Power	3-phase, 60-cycle, 115-volt

Figure 8 shows the AN/TPQ-8 set up ready for operation. Figure 9 is an over-all picture of the jamming test site at Evans Signal Laboratory, Belmar, New Jersey.

Radar Set AN/APS-23(XA-2) as used in the flight tests functions similarly to Radar Set AN/APS-23, with the exception that the AN/APS-23(XA-2) RF System is tunable (frequency synchronized transmitter and receiver) by a push button control box over a range of approximately 1000 megacycles; ie., from 8550 to 9550 megacycles. The AN/APS-23(XA-2), in connection with the APA-44 computer, functions as an airborne search navigational and bombing radar system. Navigational distances from home base are supplied to the operator within 3% of the distance from the last check point. The system is capable of 25 mil bombing accuracy at high altitudes for a straight approach under favorable weather conditions with minimum degradation in combat. The radar RF transmitter power output is from 40 to 60 KW over the tuning range.

The AN/TPQ-8 ground jammer used in these antijamming tests was located at a test site approximately 1/4 mile west of the Evans Signal Laboratory near Belmar, New Jersey. (See Figure 10). The jammer and its associated SCR-584 radar set were operated by engineers and military personnel of Evans Signal Laboratory and the Electronic Warfare Center. Direct VHF radio communication between the jammer operator on the ground and the radar operator in the aircraft was maintained during all the flight tests.

FLIGHT TESTS CONDUCTED 2 NOVEMBER 1951

The first series of flight test runs were made 2 November 1951. The aircraft flew a course from an Initial Point (hereinafter referred to as the I.P.) of a location on Little Beach, New Jersey, to a position over a target located on the New Jersey Coast at Spring Lake, a distance of approximately 45 miles. This flight course was repeated four times during this test. These flights were made at an altitude of 10,000 feet. The radar operator observed that on Run No. 4 of this test the jammer operator averaged finding and jamming the radar in one minute after each frequency change made on the AN/APS-23(XA-2) radar. This was the best average that the jammer operator was able to accomplish on this or any of the test runs performed in later tests. On this run a tactical situation was simulated by the aircraft flying out beyond the range of the tracking radar, then flying tangentially for a short distance and then heading back towards the jammer. The SCR-584 crew located the aircraft in three minutes after the radar operator advised by radio that he was beginning the run. The position of the aircraft at the start of this run was not known to the ground tracking radar crew. The aircraft did not start operating its radar until the aircraft had assumed a heading toward the jammer. The jammer was able to jam the radar in about 4 minutes from the start of this run and continued to jam the radar on an average of one-minute intervals between frequency changes made by the radar operator. The radar operator tuned his radar in varying amounts of ±400 megacycles each time he changed frequency because of jamming. Because of standing wave ratio in the system, in order to prolong the life of the 2J51

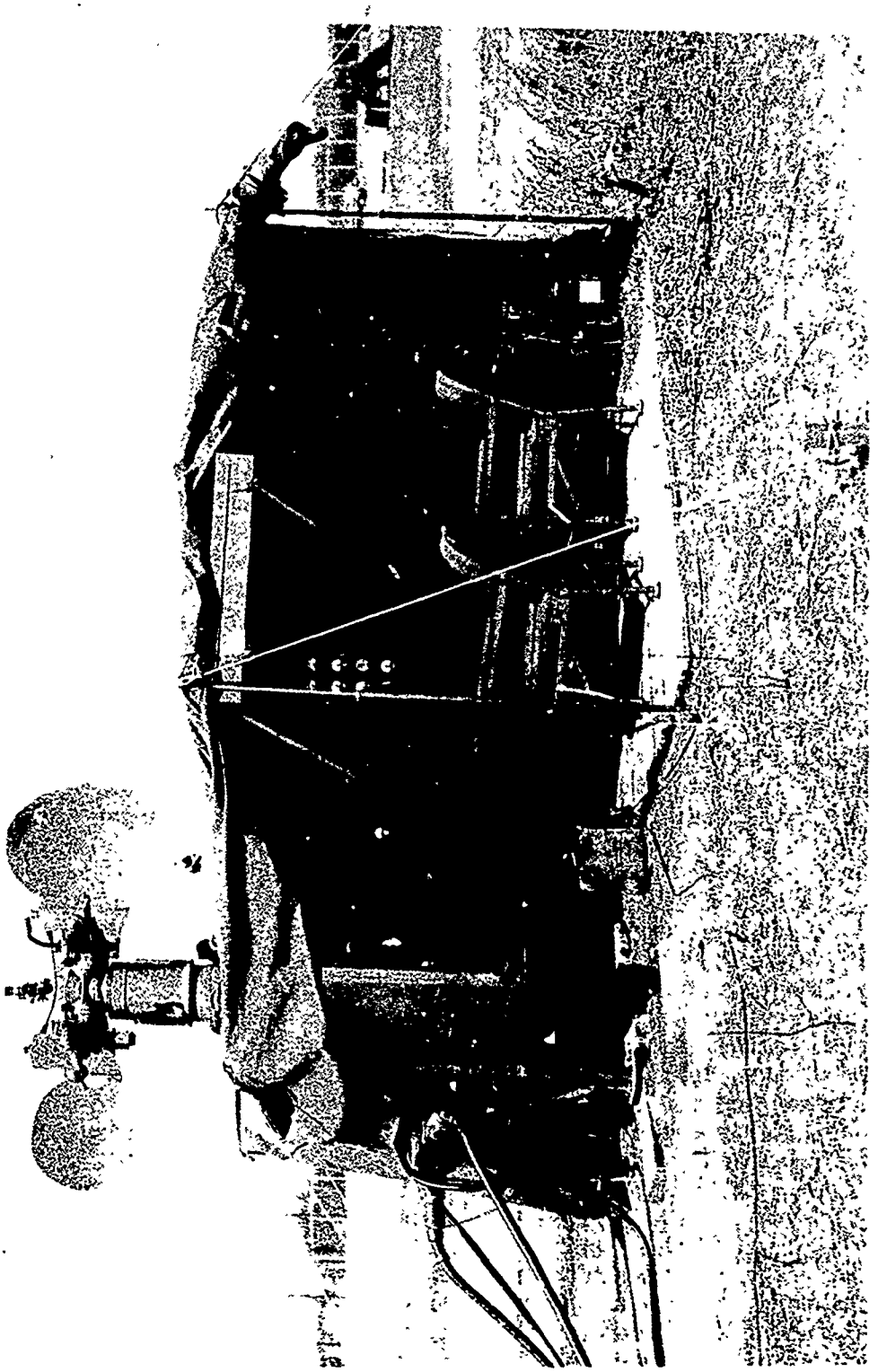


FIGURE 8. AN/TPQ-8 Showing Complete Equipment Assembled in Field Operating Position

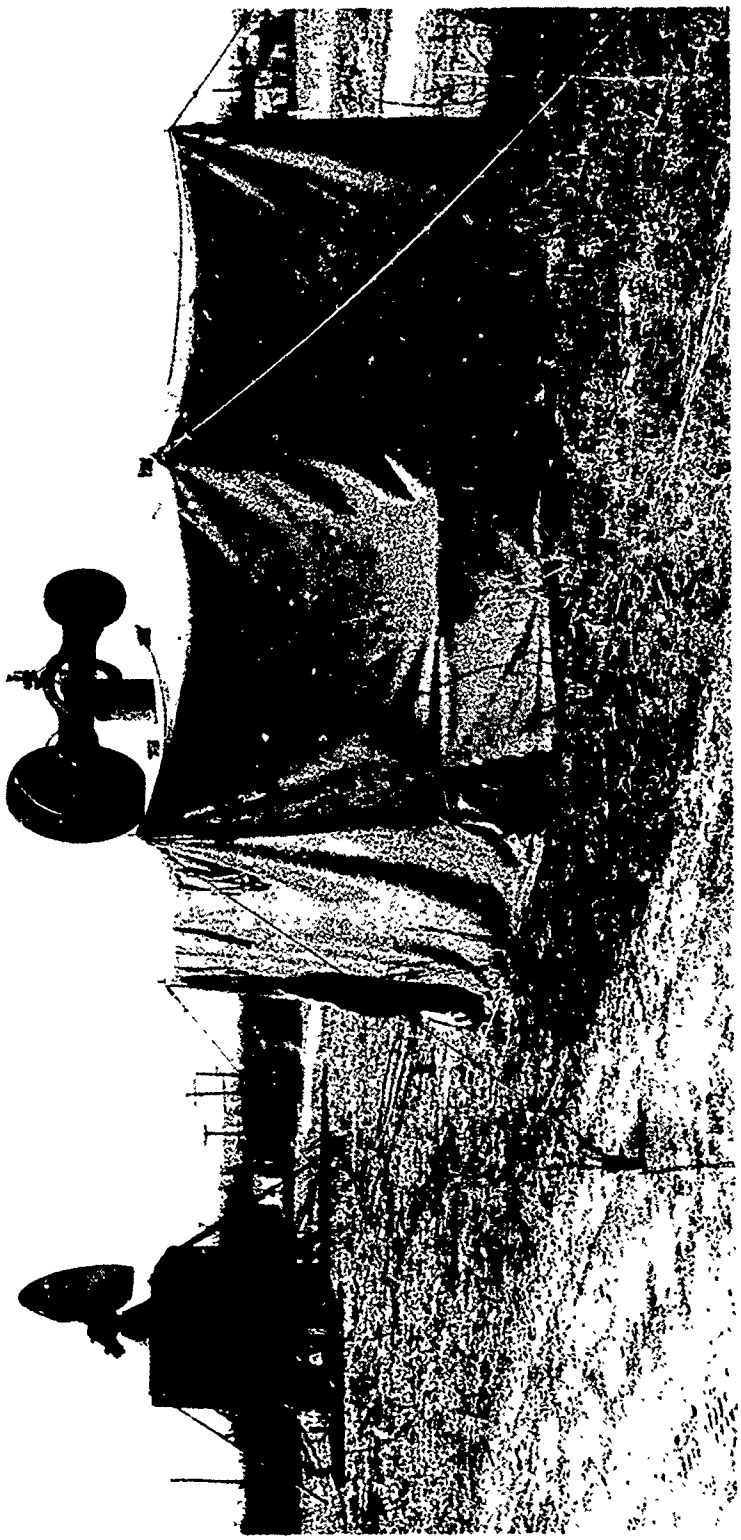


FIGURE 9. AN/TPQ-8 With Directing Radar Set AN/MPQ-16 (Modified SCR-584) Set up in Field Operating Position

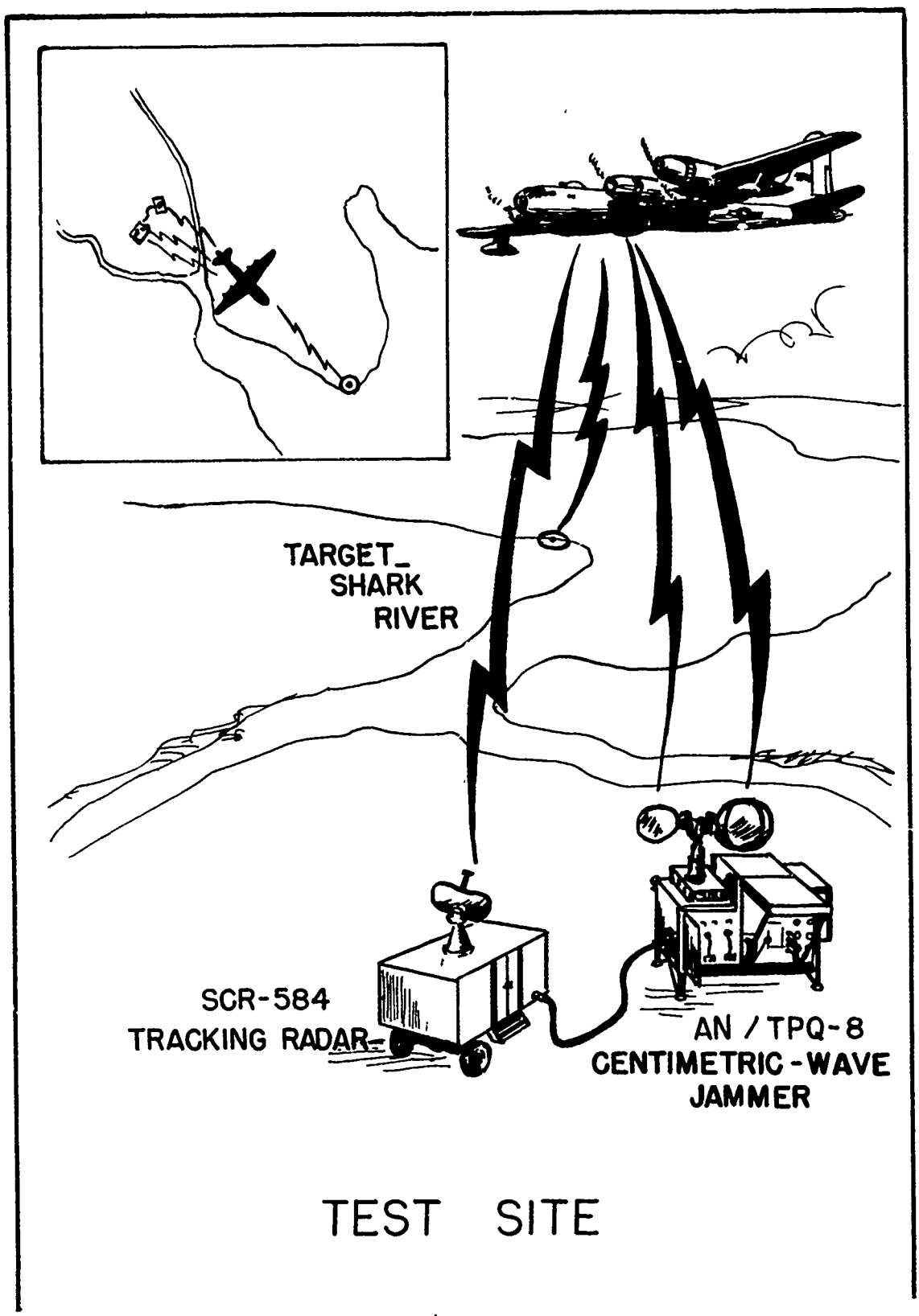


FIGURE 15. Test Site

magnetron in the airborne radar, it was decided to keep from tuning it closer than 100 megacycles from either end of its range. At the completion of the test runs for this day, the aircraft returned to W-P AFB, Dayton, Ohio, where plans were made for the next series of antijamming tests. The AN/APS-23(XA-2) operators, the jammer and the SCR-584 crews gained experience in coordinating their respective efforts in conducting this test, which greatly facilitated the smooth working of the many test runs that followed. The data recording device is a special camera developed by the Antijamming Research Unit of the Aircraft Radiation Laboratory to give a photographic record of the operation of airborne radar during tests. For the purpose of the tests described in this report, the data recorder was installed in such a manner as to give a photographic record of seven functions pertinent to analyzing the results of the tests. These functions are indicated on instruments as follows:

1. Meter indicating frequency at a given time in kilo-megacycles (lower left).

2. Meter indicating strength of jamming signal at the second detector of the radar receiver, (lower right).

3. Clock showing time, (upper right).

4. Selsyn #1 showing setting of radar IF gain control.

5. Selsyn #2 showing setting of antenna tilt control.

6. Selsyn #3 showing setting of contrast control.

7. Counter showing picture frame number.

FLIGHT TEST NO. 2

This flight test was conducted 11 December 1951. Extensive engineering work had to be performed on the AN/APS-23(XA -2) before this flight test could be conducted because of antenna rotary joint and power supply faults that developed in the radar during "resolution" tests. None of these, however, involved the variable frequency components.

The aircraft arrived at the test area and started on Run #1 at 1:17 Eastern Standard Time. This run was conducted in the following manner. The aircraft proceeded to the initial point, 15 miles east of Little Beach, New Jersey, and circled until picked up by the tracking radar located at the jammer site. The AN/APS-23(XA-2) operator began operating his radar from the time he began to circle the I.P. and continued operation until after the aircraft had passed the target. The target for this run was Manasquan Inlet, New Jersey. During this run the AN/APS-23(XA-2) was operated with PPI presentation with data recorded on each rotation of the indicator sweep. When the ground tracking radar crew notified the aircraft via radio that the aircraft was being tracked, the aircraft proceeded on its run to the target, taking pictures as described. Figure 11 shows some of the photographs taken during this run. On this run frequency

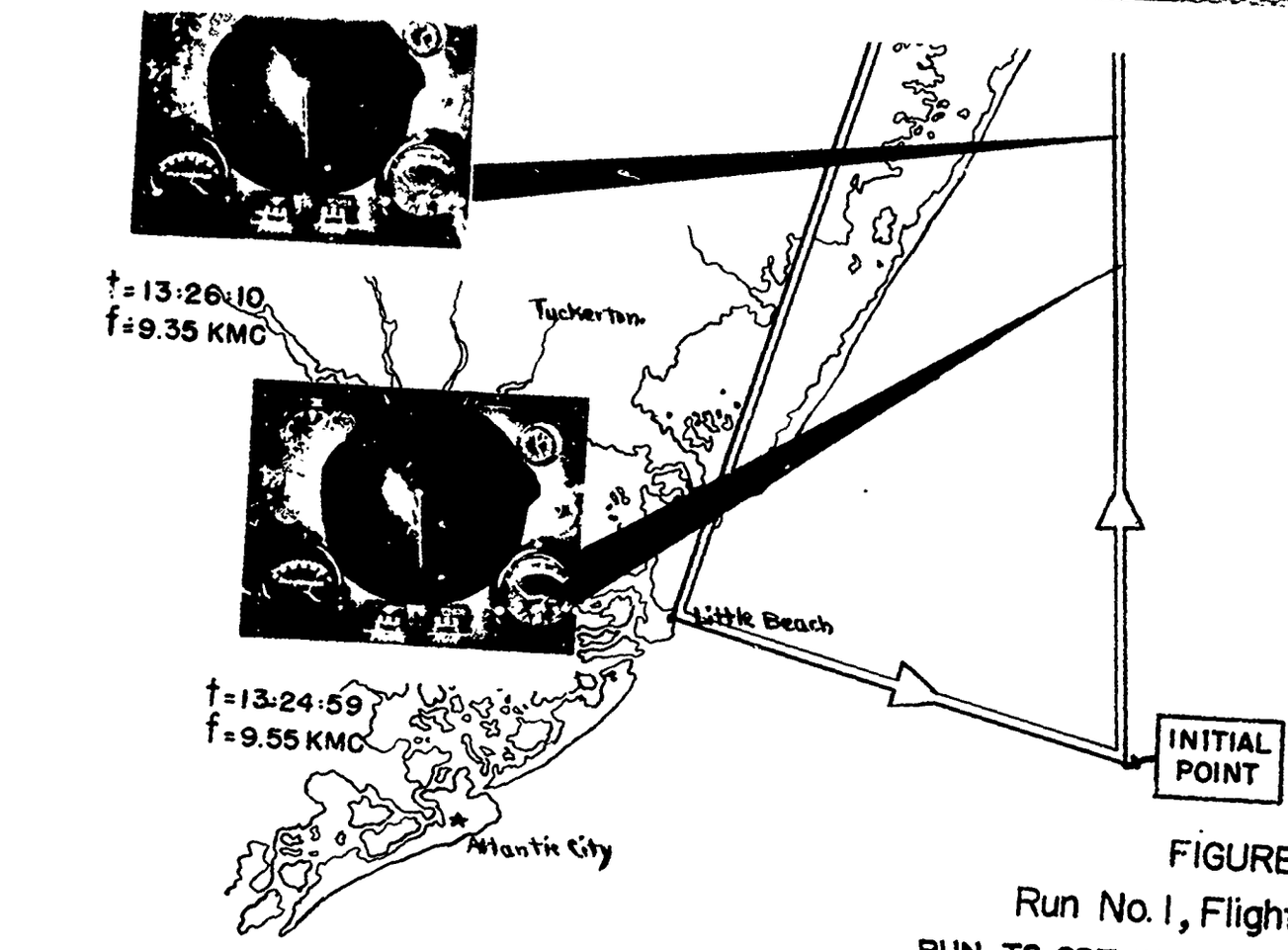
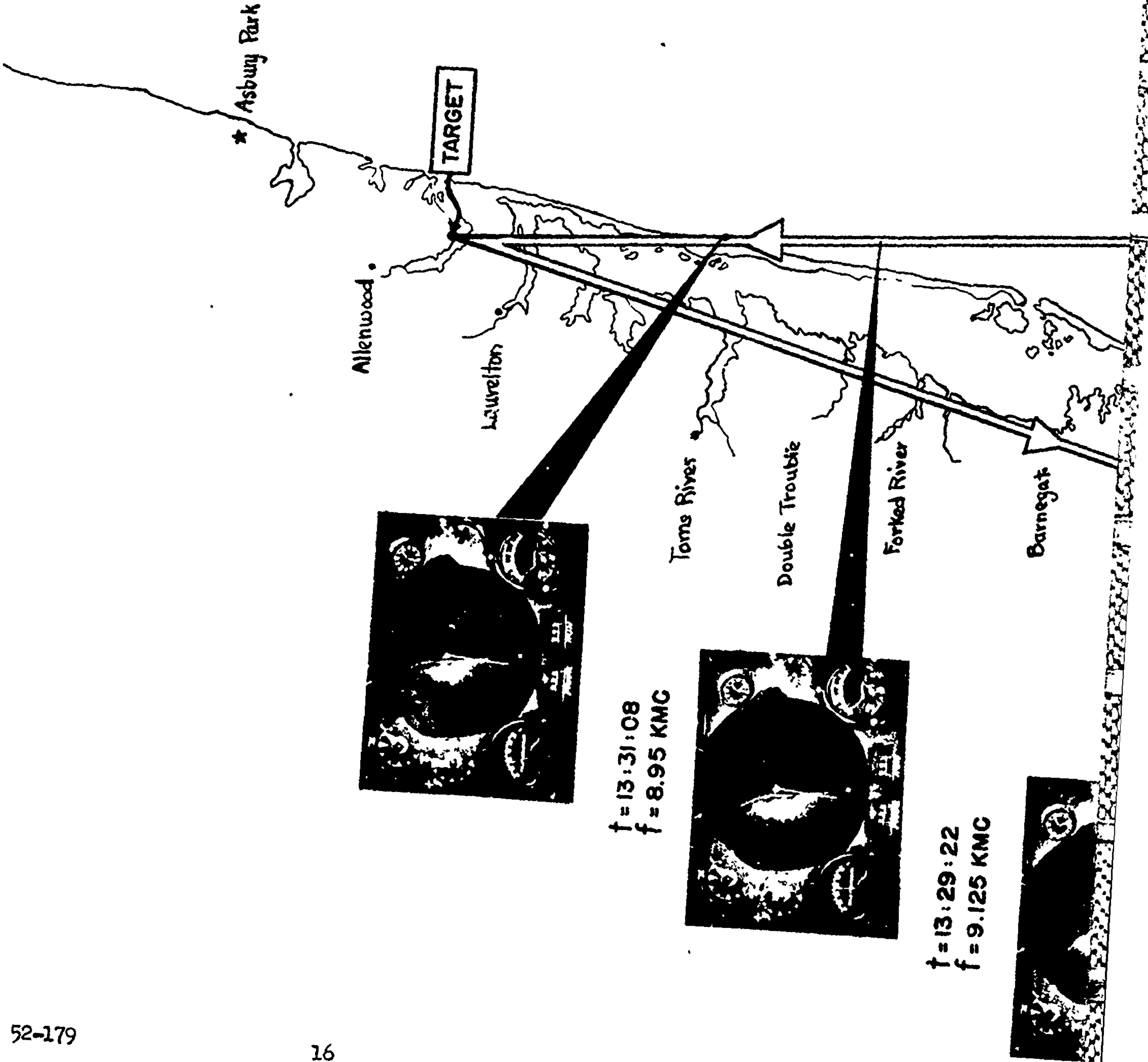


FIGURE 11

Run No. 1, Flight Test No. 2

RUN TO OBTAIN UN-JAMMED SCOPE PICTURES OF FLIGHT TEST COURSE FROM AN ALTITUDE OF 10,000. CHANGES IN FREQUENCY WERE MADE DURING THIS FLIGHT.


Asbury Park
TARGET
Allenwood
Laurelton
Toms River
Double Trouble
Forked River
Barnegat
t = 13:31:08
f = 8.95 KMC
t = 13:29:22
f = 9.125 KMC

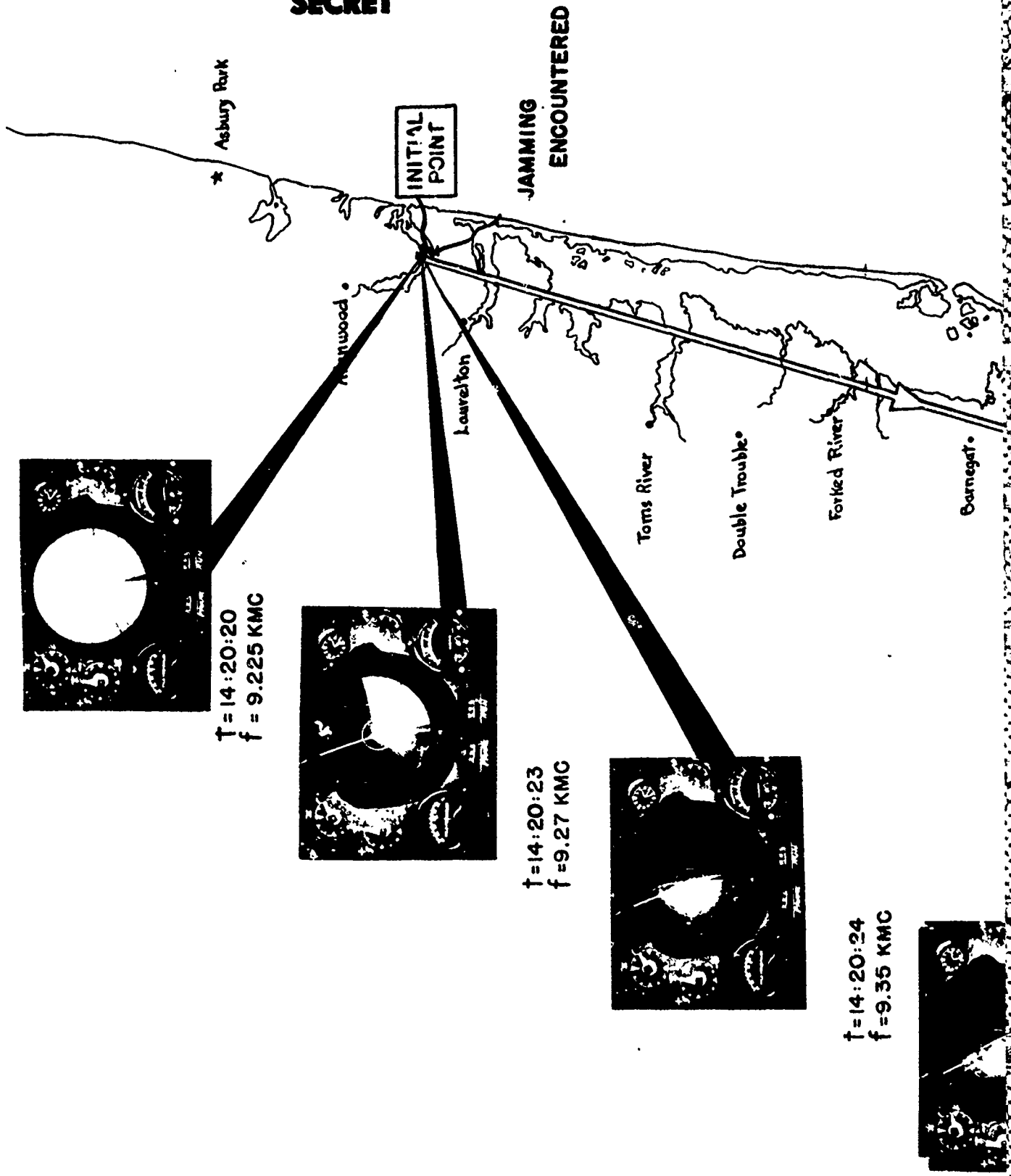
changes were made by the radar operator. No jamming was used on this run, the purpose being to ascertain whether all the equipments were operating properly and how much viewing time is lost due only to frequency shift and AFC action in the AN/APS-23(XA-2). As a result of this run, the aircraft radar operator reported that he could observe echoes during the time he was changing frequency and that the echoes were a bit blurred; however, he could distinguish the echoes easily. The radar operator also reported that occasionally it required from 1 to 2 seconds for the AFC to regain receiver frequency alignment after the radar was changed in frequency by amounts of 100 mcs or more. When changes of approximately 50 mcs or less were made, this delay was not present.

Run #2 was made with the aircraft flying from the target, Manasquan Inlet, New Jersey, out to the I.P., Little Beach, New Jersey, a distance of 45 miles. This run was conducted in the following manner. The radar was operated with PPI presentation and with data recorded on every sweep.

The aircraft circled the jammer site with its radar operating until the radar operator received word via radio that the jammer crew was ready for action and then proceeded to the I.P. The AN/TPQ-8 jammer was turned on after the aircraft reached a position over the I.P.; the jammer operator and the AN/APS-23 (XA-2) operator tried to jam and evade jamming, respectively. The airborne radar operator shifted his frequency whenever his scope showed jamming and made random tuning jumps of 100 to 500 megacycles at a time. During this run, the aircraft radar operator attempted to time his frequency shifts so that the new frequency took effect when the sweep was about 90° to the left of the aircraft heading. The tuning motor for the magnetron in the AN/TPQ-8 stuck several times during the operation of this run; therefore, data as planned was not obtained. This run was repeated.

Repeat of Run #2. This run was conducted in the same operational manner over the same course as the first Run #2. The radar operator reported that the jammer operator required an average of two minutes to find the radar frequency and jam the airborne radar for each time the frequency of the AN/APS-23(XA-2) was changed during this run. Figure 12 shows some of the scope pictures of the AN/APS-23(XA-2) on this flight run. There were times during this run when the radar operator tuned across the jamming signal showing, momentarily, jamming on the scope unknown to the jammer crew. On this run the dummy antenna load was used occasionally when the radar was being tuned. Provision is made whereby, at the will of the operator, a dummy antenna load is automatically switched to the radar when the radar is being tuned, thus the radar does not emit a signal to aid the jammer crew in locating frequencies to which the radar is being tuned nor indicate the direction of frequency change.

Run #3 was conducted with the aircraft flying from the I.P., Little Beach, to target, Manasquan Inlet. This run was performed identically to Run #2 with the one exception that the aircraft radar was operated with the sector scan presentation. Figure 13 shows the effects on the indicator scope of jamming and the antijamming performance of the airborne radar on this run. Frame #452 shows the indicator as it appears when the dummy load is in use.


JAMMING ENCOUNTERED
INITIAL POINT
Asbury Park
Lakewood
Lakehurst
Toms River
Double Trouble
Forked River
Barnegat
T=14:20:20
f = 9.225 KMC
T=14:20:23
f=9.27 KMC
T=14:20:24
f=9.35 KMC

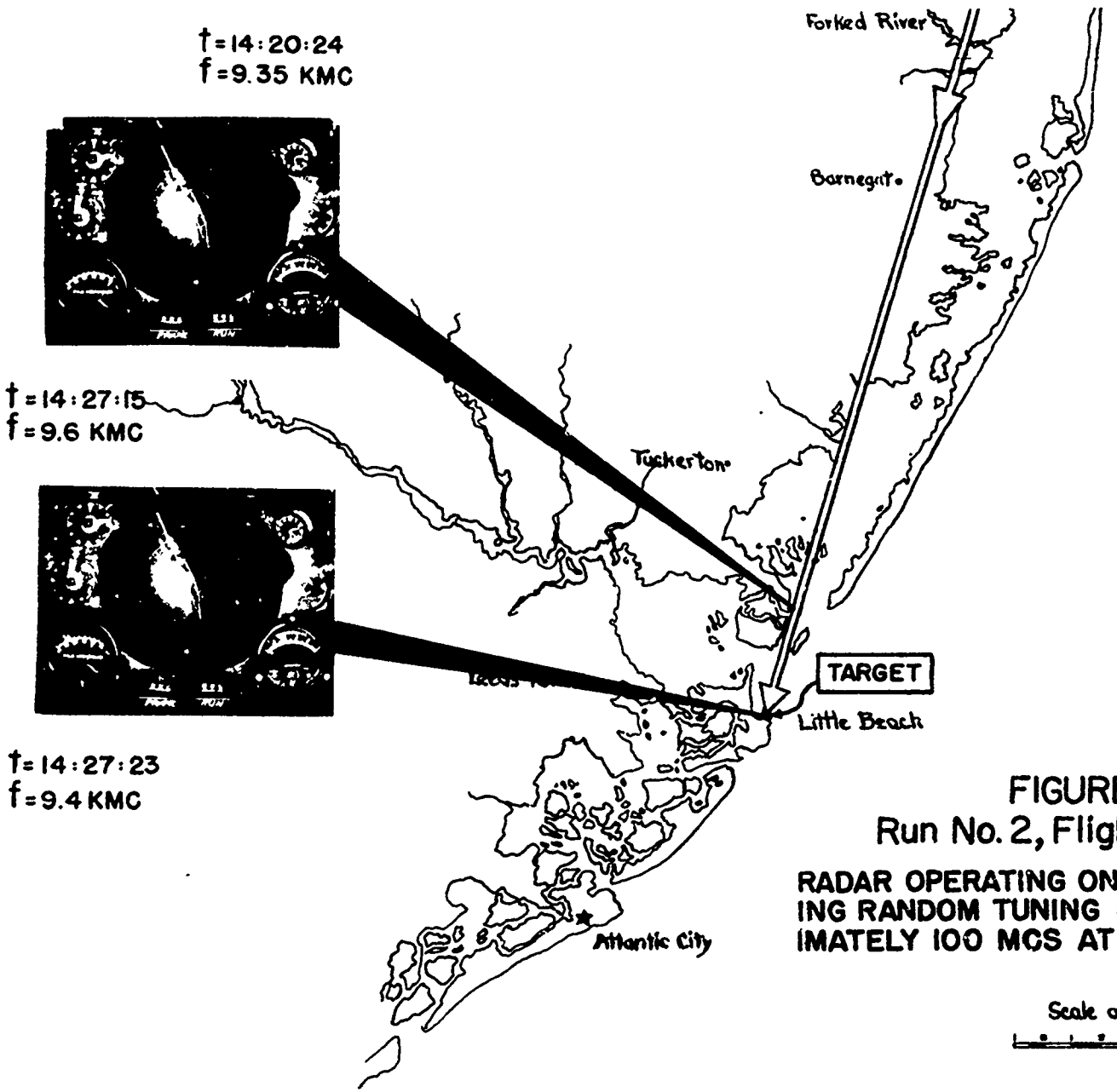
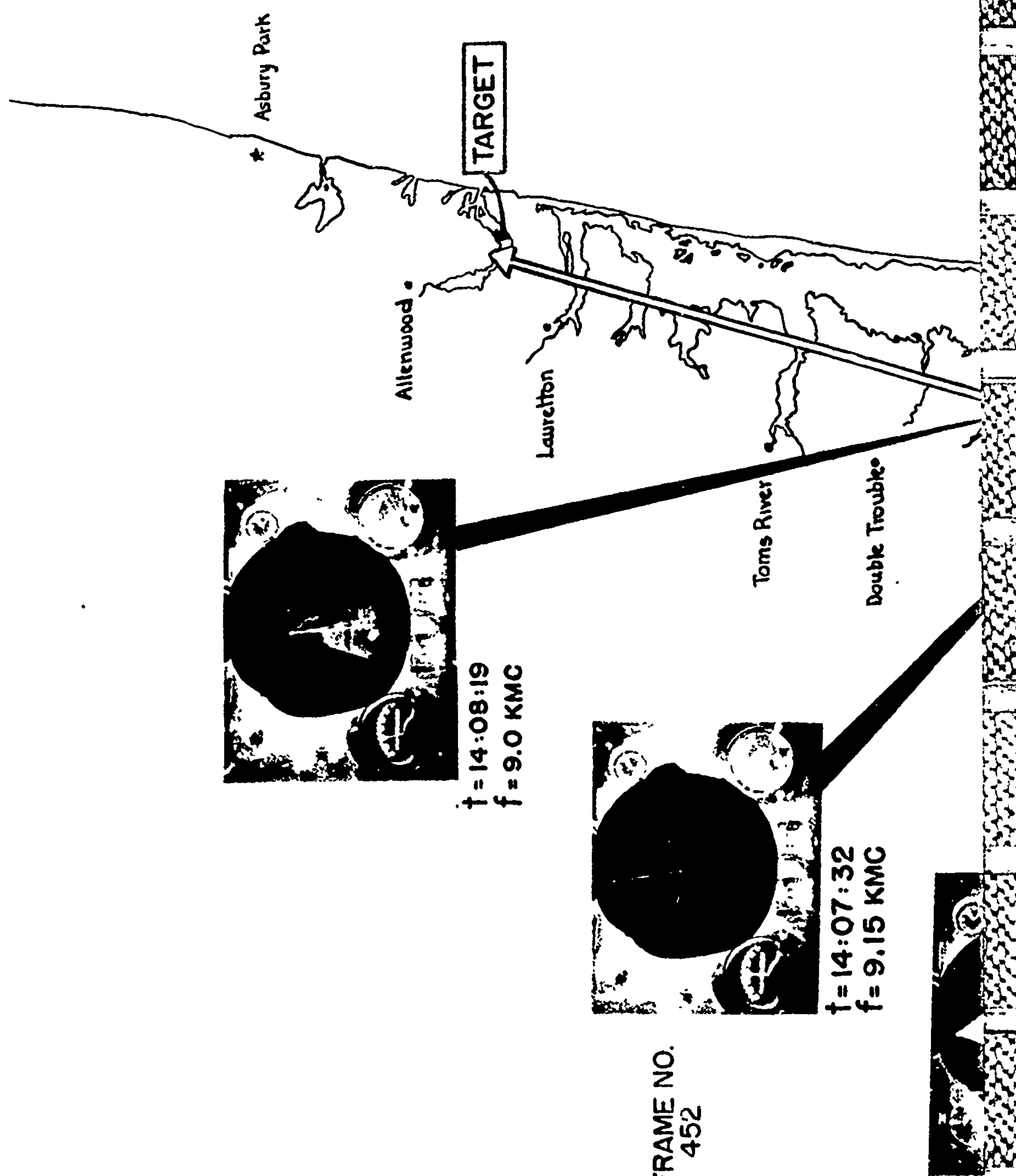


FIGURE 12
Run No. 2, Flight Test No.2

RADAR OPERATING ON PPI SCAN MAKING RANDOM TUNING JUMPS OF APPROXIMATELY 100 MCS AT A TIME.

Scale of Miles


Asbury Park
TARGET
Allenwood
Lauretton
Toms River
Double Trouble
t = 14:08:19
f = 9.0 KMC
t = 14:07:32
f = 9.15 KMC
FRAME NO.
452

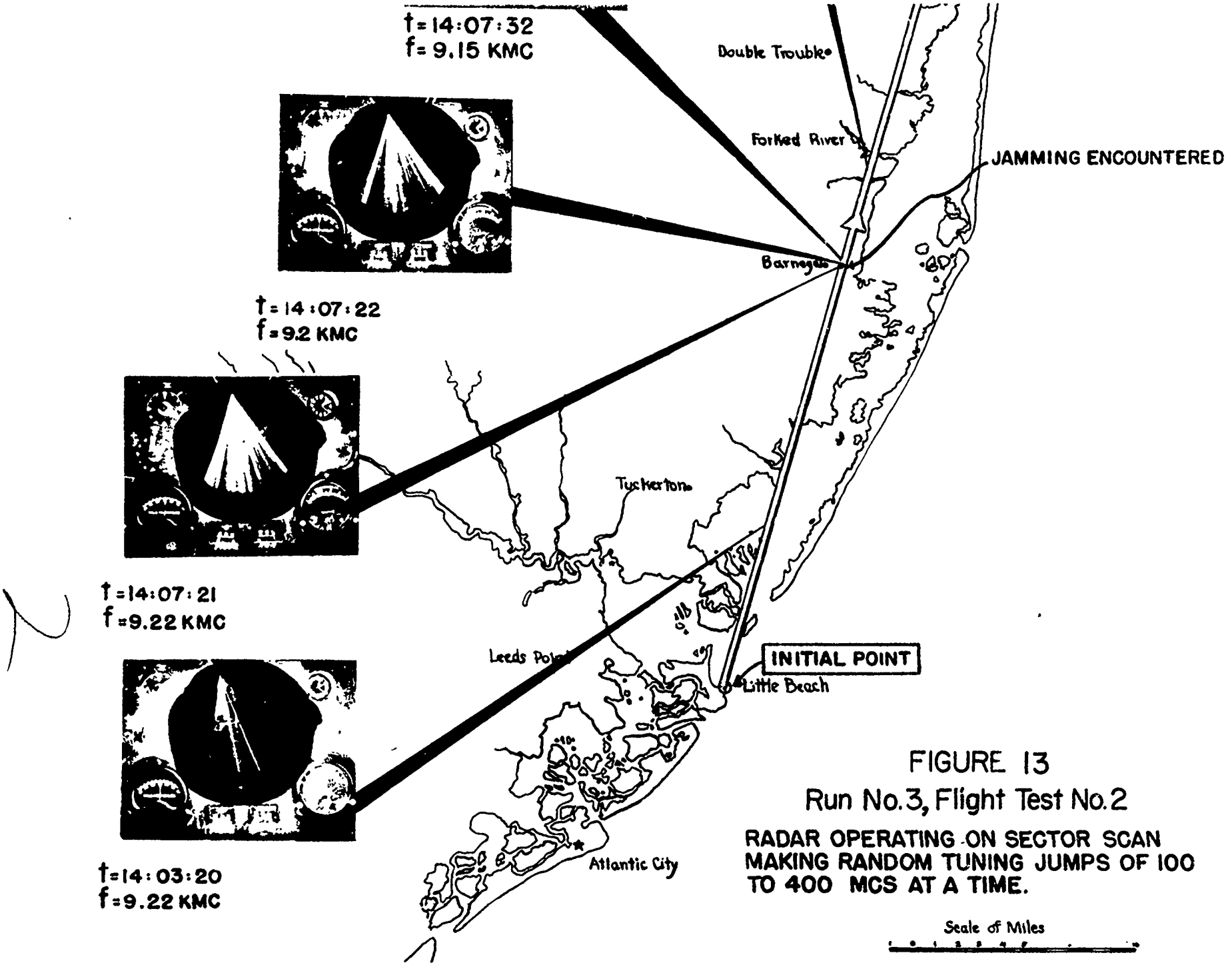


FIGURE 13

Run No. 3, Flight Test No. 2

RADAR OPERATING ON SECTOR SCAN MAKING RANDOM TUNING JUMPS OF 100 TO 400 MCS AT A TIME.

Run #4 was conducted to simulate a tactical situation. The aircraft started its flight at the I.P., Little Beach, New Jersey, and flew to a position over Atlantic City, New Jersey, then flew tangentially for some distance and came into a new I.P. located over the ocean 15 miles east of Little Beach. From this I.P. the aircraft proceeded to the target, Manasquan Inlet. The ground radar crew did not know the direction of this heading. The aircraft did not operate its radar until it assumed its heading toward the target. The ground radar crew did not have any radio information regarding the location of the aircraft when it headed toward the target. The SCR-584 found the aircraft, losing and regaining automatic tracking several times during this run. On one occasion during this run, from the time the SCR-584 lost track until track was regained and jamming appeared on the radar, eight minutes elapsed. During this flight test the AN/APS-23(XA-2) radar operator was able to shift the radar frequency to receive echoes from the same targets and be entirely free of jamming in an average time of 1-3/4 seconds from the time he encountered jamming. This was a fairly consistent figure for all the runs of the flight tests described in this report. Figure 14 shows pictures of the radar indicator taken during a portion of this run.

Run #5. This run was a rough selectivity test and was conducted as follows: The jammer frequency was held at 9115 megacycles for this run. The aircraft flew from the target to the I.P. and then headed west for Wright-Patterson Air Force Base. As soon as the airborne radar operator could tune to the jammer frequency, he switched the radar to "Manual" which disconnects the dummy load waveguide switch and the radar operator tuned the radar away from the jammer frequency until the jamming was no longer visible on the scope. The frequency indicator was photographed, then the radar was tuned to the other side of the jammer frequency and this point was likewise recorded. This procedure was repeated several times before the aircraft had flown approximately 90 miles, at which point the SCR-584 lost track of the aircraft, thereby causing the TPQ-8 to lose its directivity. The AN/APS-23(XA-2) radar operator reported seeing jamming at the 90-mile point just before the SCR-584 lost track. On one of the selectivity operations as described on this run, the radar operator noted that by tuning the airborne radar to 9175 megacycles and then to 9210 megacycles, his scope became free of jamming; this tuning was to either side of 9190 megacycles the center frequency of the jammer at which it jammed the scope completely. Figure 15 shows some of the pictures taken of the radar scope during this run.

When the aircraft was located at distances of 20 miles and less from the jammer, the amount of frequency shift necessary in order to clear the scope was somewhat less than the 25 megacycles required to accomplish the same purpose when the aircraft was from 50 to 60 miles distant from the jammer. However, no frequency vernier was available and no conclusions were drawn therefrom, since jammer factors, such as directivity and parallax, were involved. The B-50 aircraft containing the AN/APS-23(XA-2) flew at an altitude of 10,000 feet during all the flight runs of flight test No. 2.

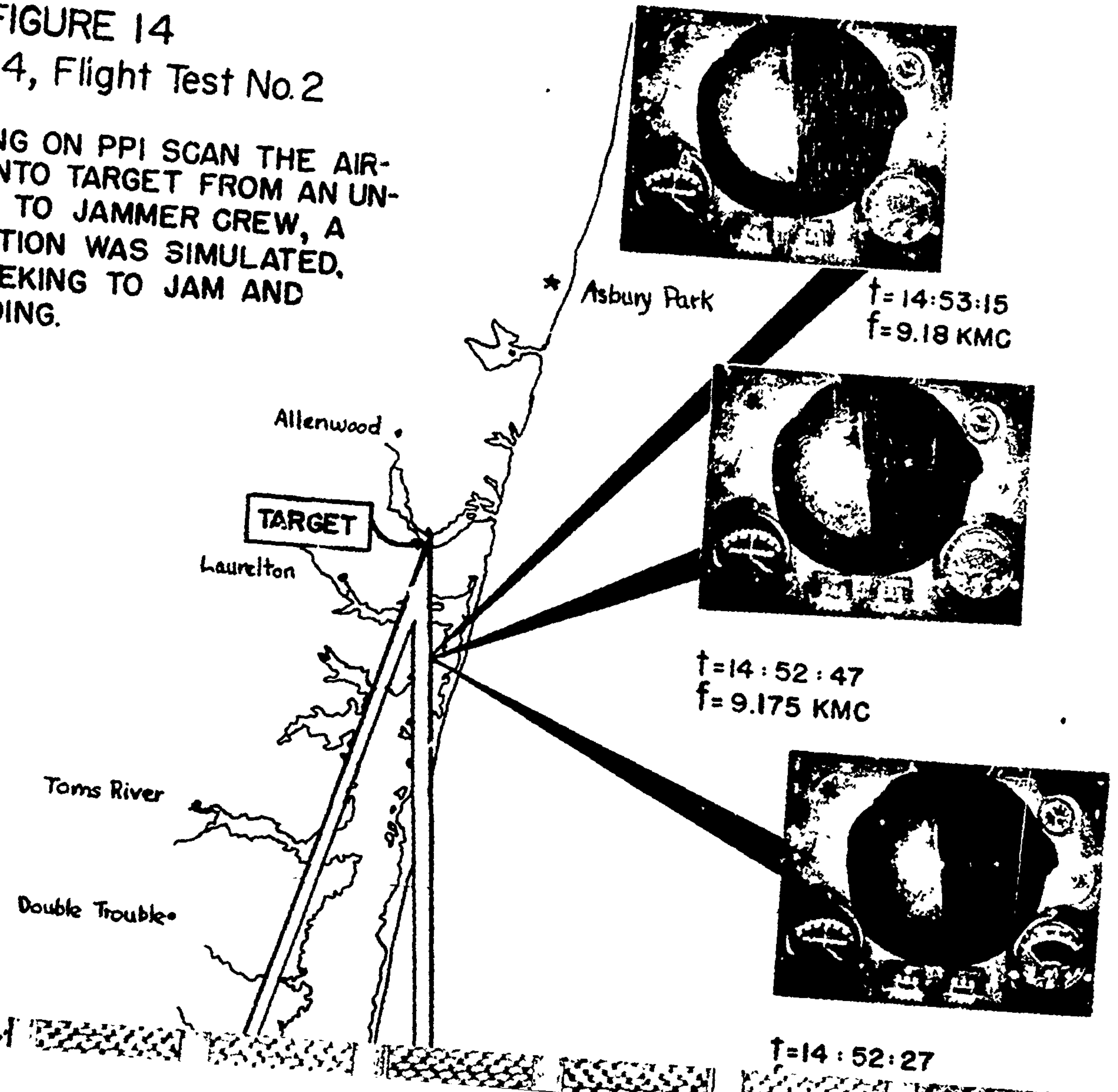
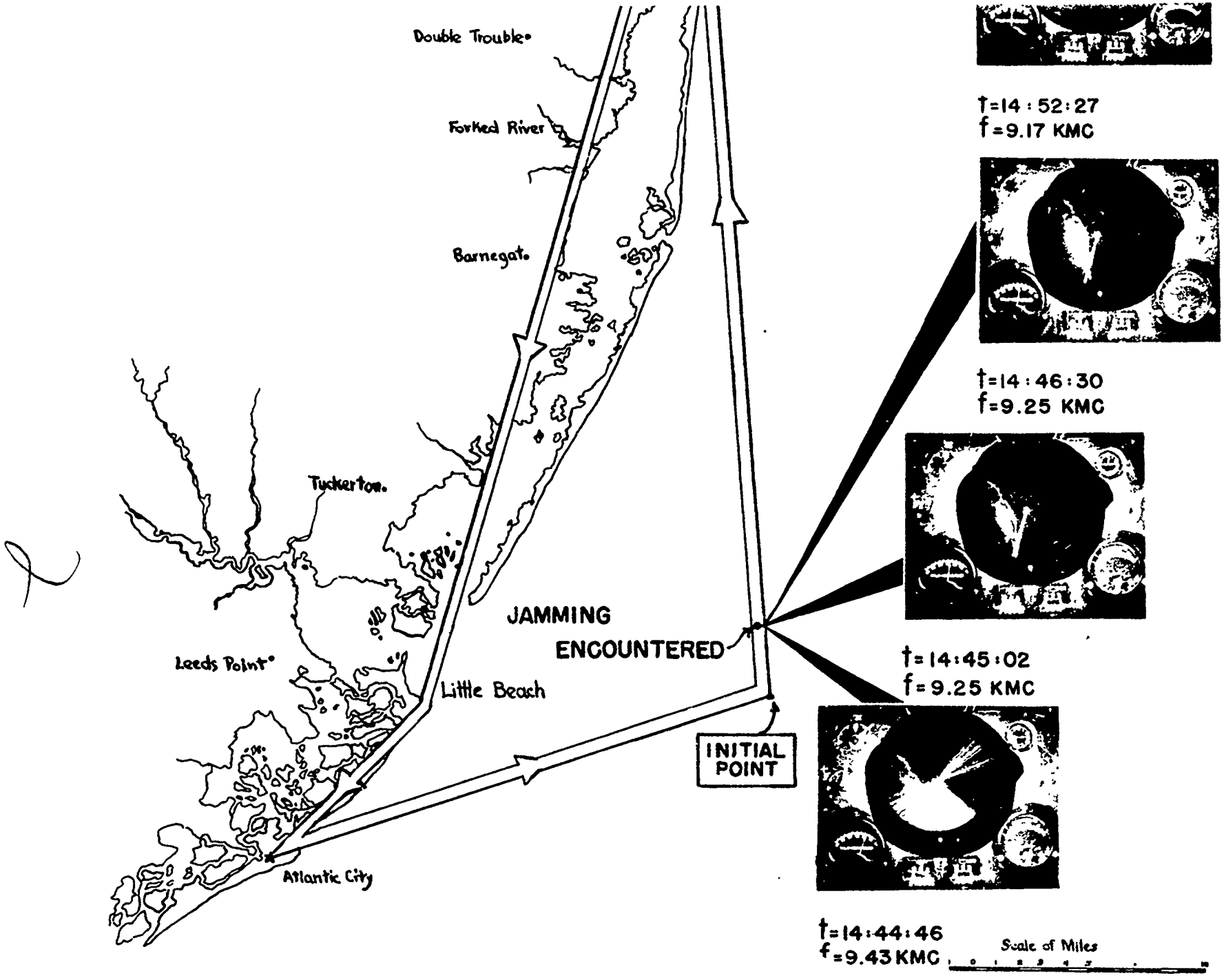
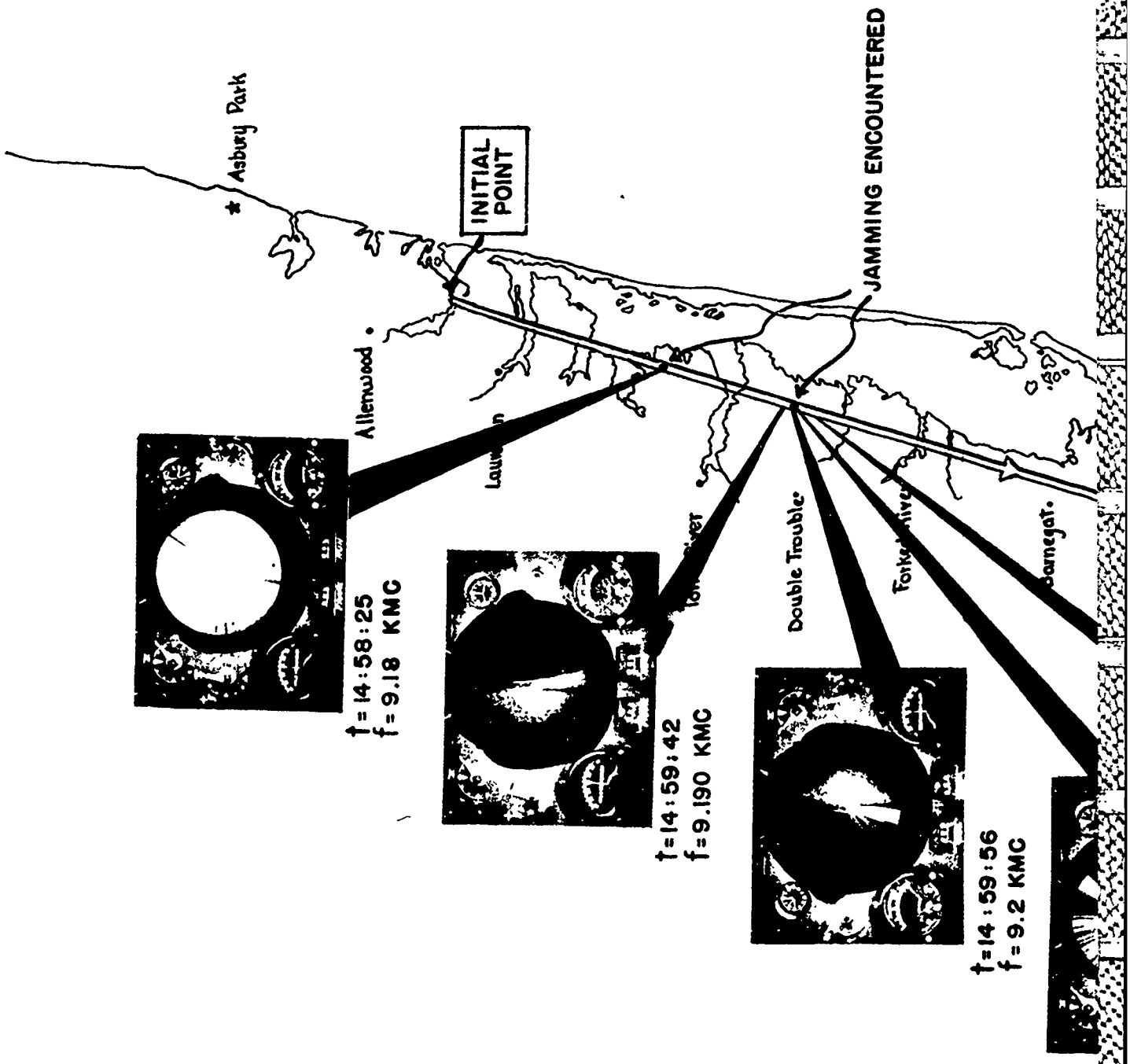


FIGURE 14
Run No. 4, Flight Test No. 2

RADAR OPERATING ON PPI SCAN THE AIRCRAFT COMING INTO TARGET FROM AN UNKNOWN HEADING TO JAMMER CREW, A TACTICAL SITUATION WAS SIMULATED, THE JAMMER SEEKING TO JAM AND THE RADAR EVADING.


Double Trouble
Forked River
Barnegat
Tuckerton
Leeds Point
Little Beach
Atlantic City
JAMMING
ENCOUNTERED
INITIAL
POINT
t=14:52:27
f=9.17 KMC
t=14:46:30
f=9.25 KMC
t=14:45:02
f=9.25 KMC
t=14:44:46
f=9.43 KMC
Scale of Miles


Asbury Park
INITIAL POINT
JAMMING ENCOUNTERED
Allenwood
Double Trouble
t=14:58:25
f=9.18 KMC
t=14:59:42
f=9.190 KMC
t=14:59:56
f=9.2 KMC

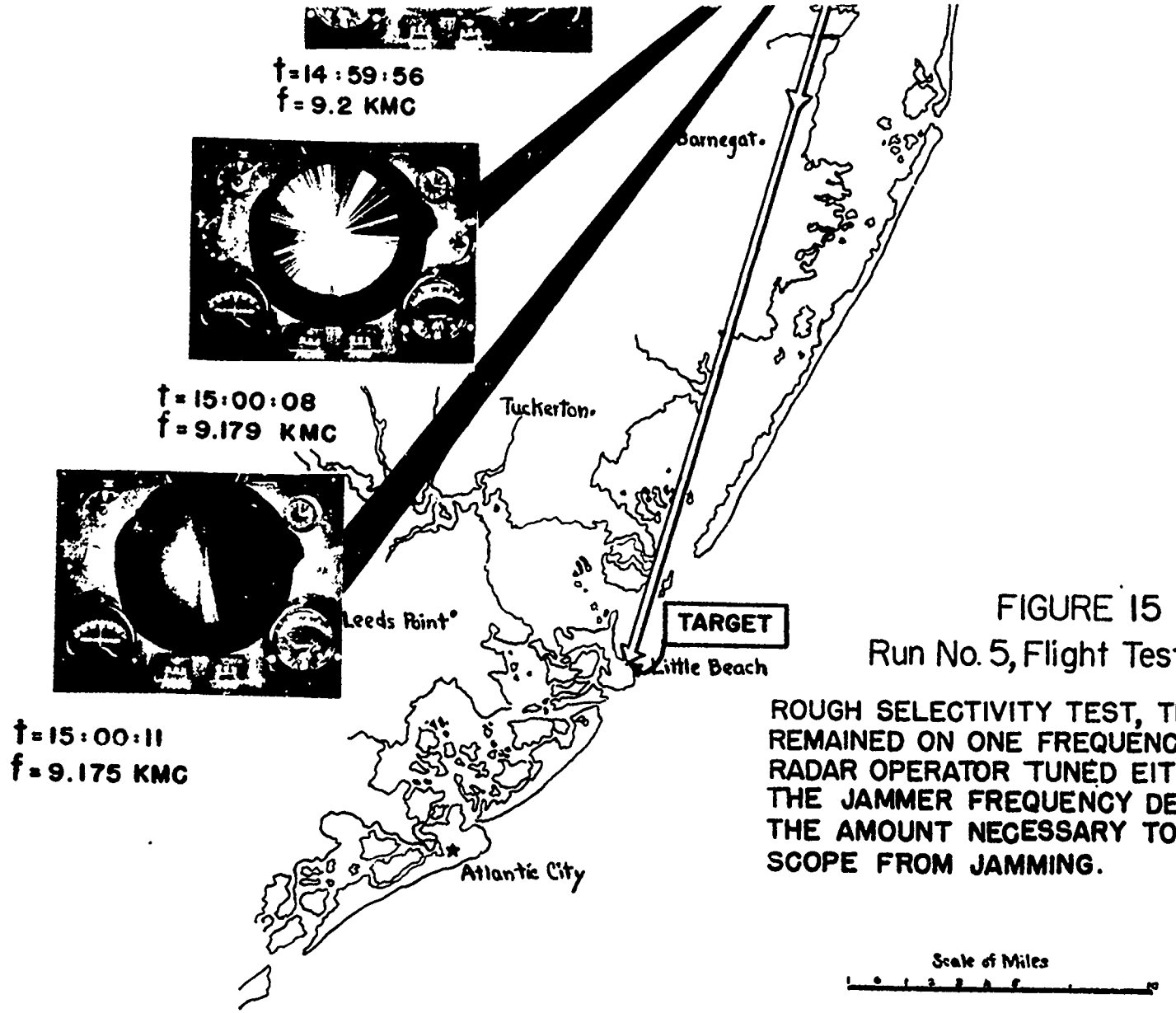


FIGURE 15

Run No. 5, Flight Test No. 2

ROUGH SELECTIVITY TEST, THE JAMMER REMAINED ON ONE FREQUENCY AND THE RADAR OPERATOR TUNED EITHER SIDE OF THE JAMMER FREQUENCY DETERMINING THE AMOUNT NECESSARY TO FREE THE SCOPE FROM JAMMING.

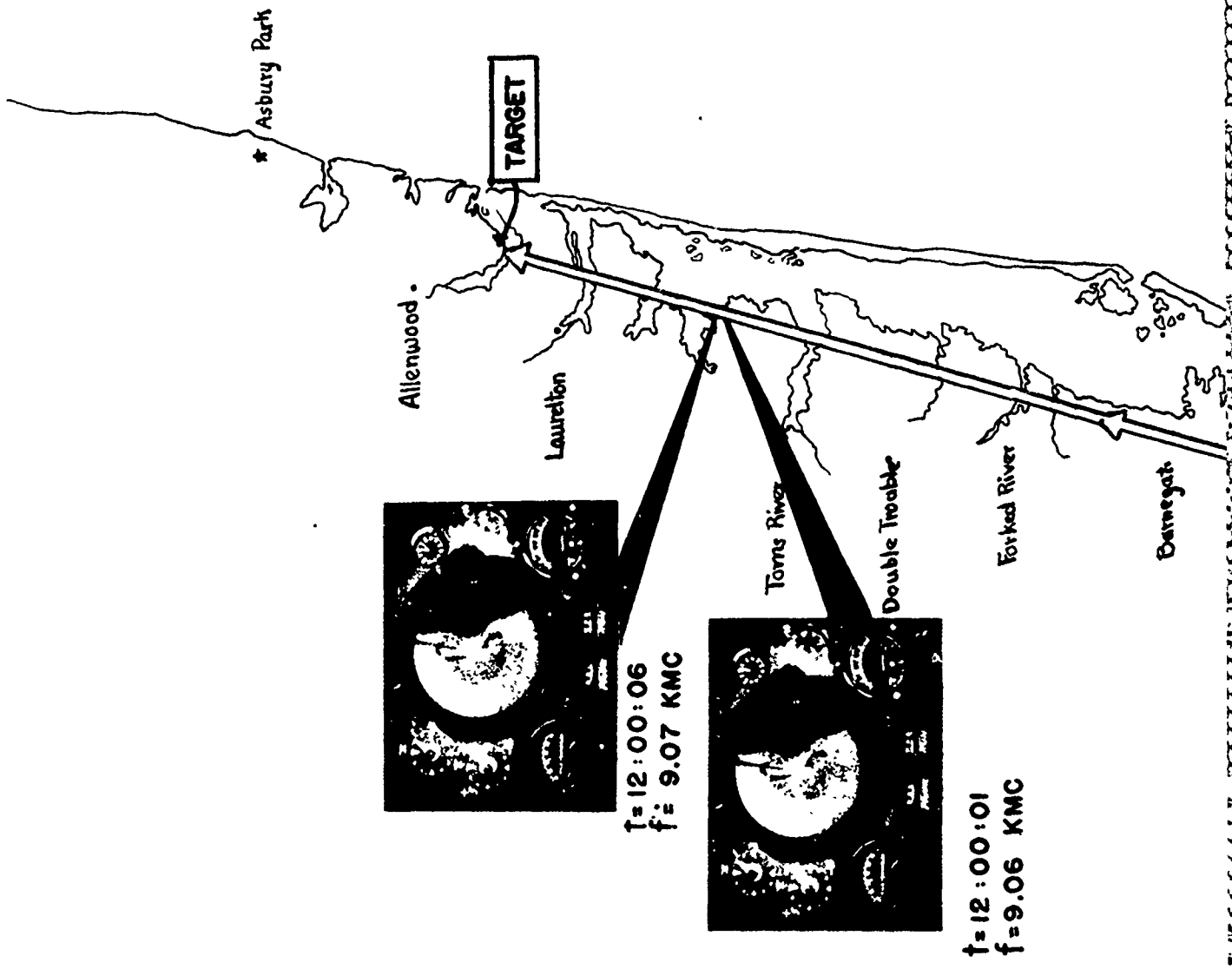
FLIGHT TEST NO. 3

This flight test, the last in the series described in this report, was conducted 25 February 1952. All flights on this test were flown at 20,000 feet altitude. The aircraft arrived at the initial point at Little Beach and started on Run #1. This run was made in order to determine that all of the equipments involved in the test were operating properly. Pictures were taken by the data recording device during this run. Pictures were obtained at several radar frequency settings along the flight path before reaching the I.P., showing radar echoes with no jamming present, see Figure 16. The target on this run was a jut of land in Shark River. The jammer site containing the AN/TPQ-8 and the SCR-584 was located at the Evans Signal Laboratory, as during the previous tests.

Run #2 was conducted in the following manner. The radar operator made a simulated bomb run using sector scan; the radar operator set the computer for automatic steering to the target from the I.P. (Sharkey Method) while the aircraft was approximately 50 miles from the target; the radar was then switched into dummy load until the aircraft was 20 miles from the target. During this 20 miles the radar was operated just enough to provide tracking corrections to the computer; the radar operator changed frequency during this run without waiting for jamming to appear on the scope. During this run the ground jammer operator observed the radar transmission only once. The jammer contacted the radar once during this test run; however, the radar operator pushed the tuning control button and the indicator was instantly cleared of jamming. An important result of this run was that, although the jammer was only able to jam at one time during the entire run, the action of the radar operator in random tuning resulted in tuning across the jammer signal several times, thus in effect momentarily jamming the radar by this action. Because of the results of this test run, it is concluded that in tactical operations against a jammer of the AN/TPQ-8 type, it might be advisable for the radar operator not to tune the radar until jamming appeared on the scope. Figure 17 shows pictures of the radar scope taken during this test run. Figure 17 shows the I.P., the target, and direction of flight of the aircraft.

Run #3 was performed by the radar operator using sector scan from the I.P. to the jammer; however, the computer was not preset at the I.P. for steering to the target. The course, I.P., and target were the same as in Run #2 above; the results of this run were identical with the results of Run #2. Figure 18 shows pictures of the AN/APS-23(XA-2) radar indicator taken during this run with I.P., target and direction of flight of the aircraft.

Run #4 was conducted in the same manner as Run #4 of Flight Test #2. That is, it was made in a manner to simulate a tactical operation. At times during this run, the radar operator switched to the dummy antenna load when he was changing frequency, thus keeping the jammer crew from knowing in which direction the airborne radar was being tuned. Also, at times during the run, the radar operator made false starts in frequency shift direction when tuning the radar; that is, started tuning in one direction for an instant and then immediately tuning to a frequency in the opposite direction. On this run the aircraft flew out beyond the tracking range of the radar and came in on a heading that was not


Asbury Park
TARGET
Allenwood
Lakewood
Toms River
Double Treable
Forked River
Barnegat
t=12:00:06
f= 9.07 KMC
t=12:00:01
f=9.06 KMC

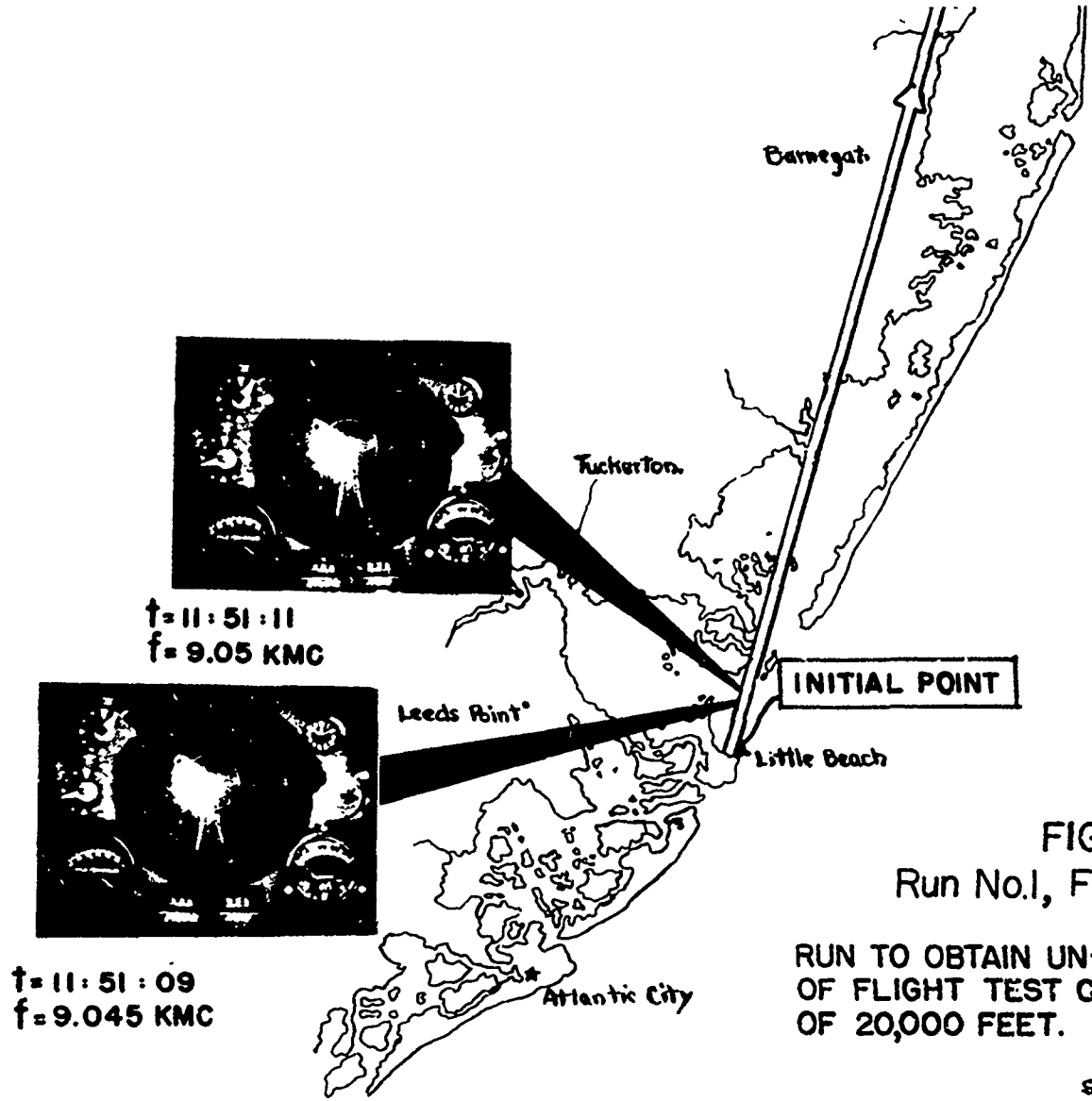
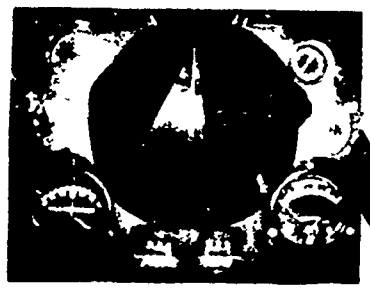


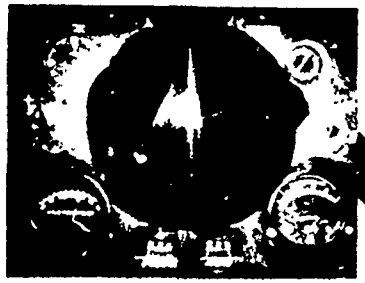
FIGURE 16
Run No.1, Flight Test No. 3

RUN TO OBTAIN UN-JAMMED SCOPE PICTURES OF FLIGHT TEST COURSE FROM AN ALTITUDE OF 20,000 FEET.

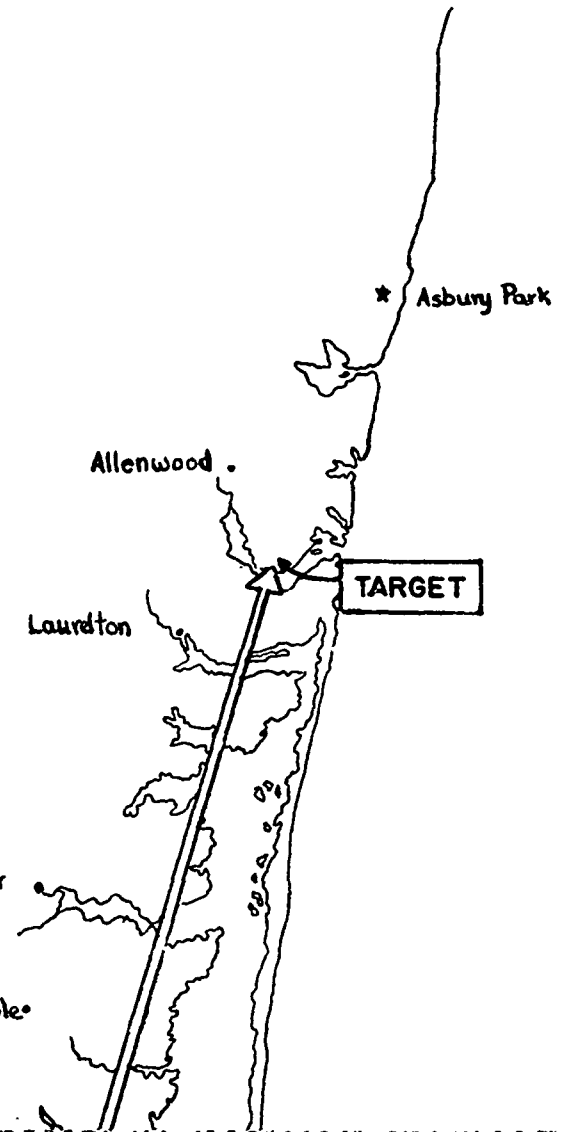
t = 12:36:09
f = 9.09 KMC



T = 12:36:07
f = 9.2 KMC



t = 12:36:05



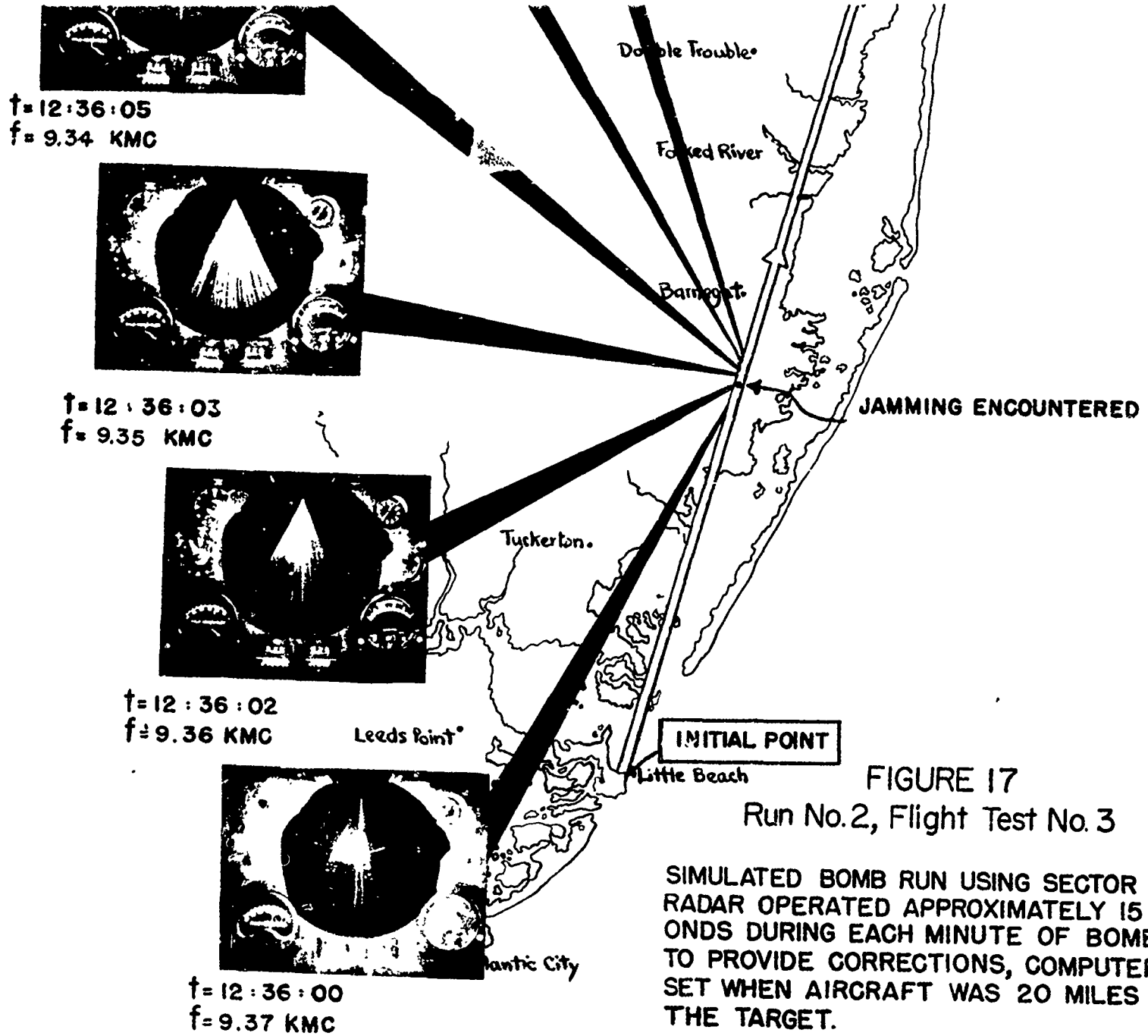
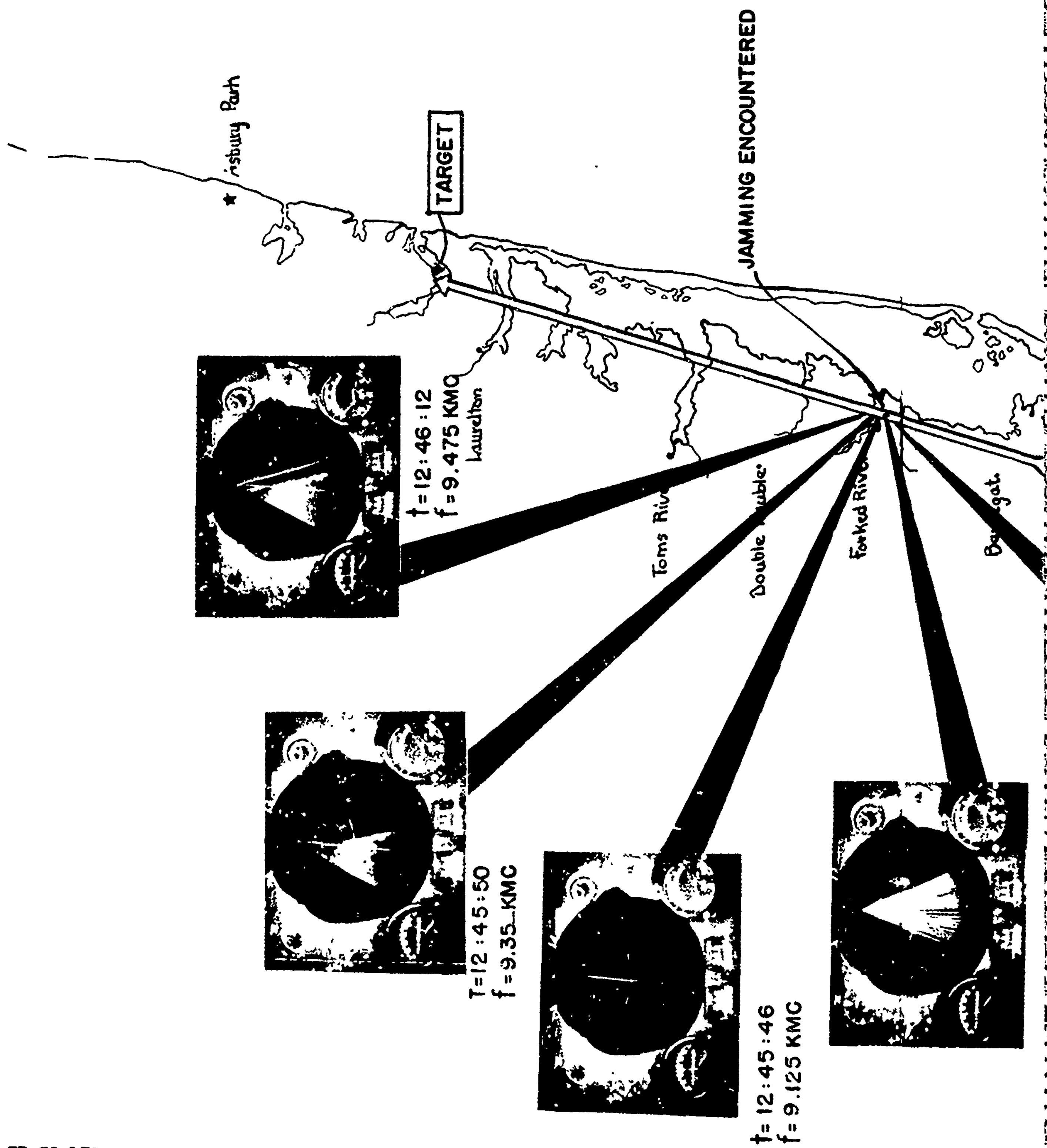


FIGURE 17

Run No. 2, Flight Test No. 3

SIMULATED BOMB RUN USING SECTOR SCAN, RADAR OPERATED APPROXIMATELY 15 SECONDS DURING EACH MINUTE OF BOMB RUN TO PROVIDE CORRECTIONS, COMPUTER WAS SET WHEN AIRCRAFT WAS 20 MILES FROM THE TARGET.


TARGET
JAMMING ENCOUNTERED
Asbury Park
Laurelton
t = 12:46:12
f = 9.475 KMC
T = 12:45:50
f = 9.35 KMC
t = 12:45:46
f = 9.125 KMC
Forked River

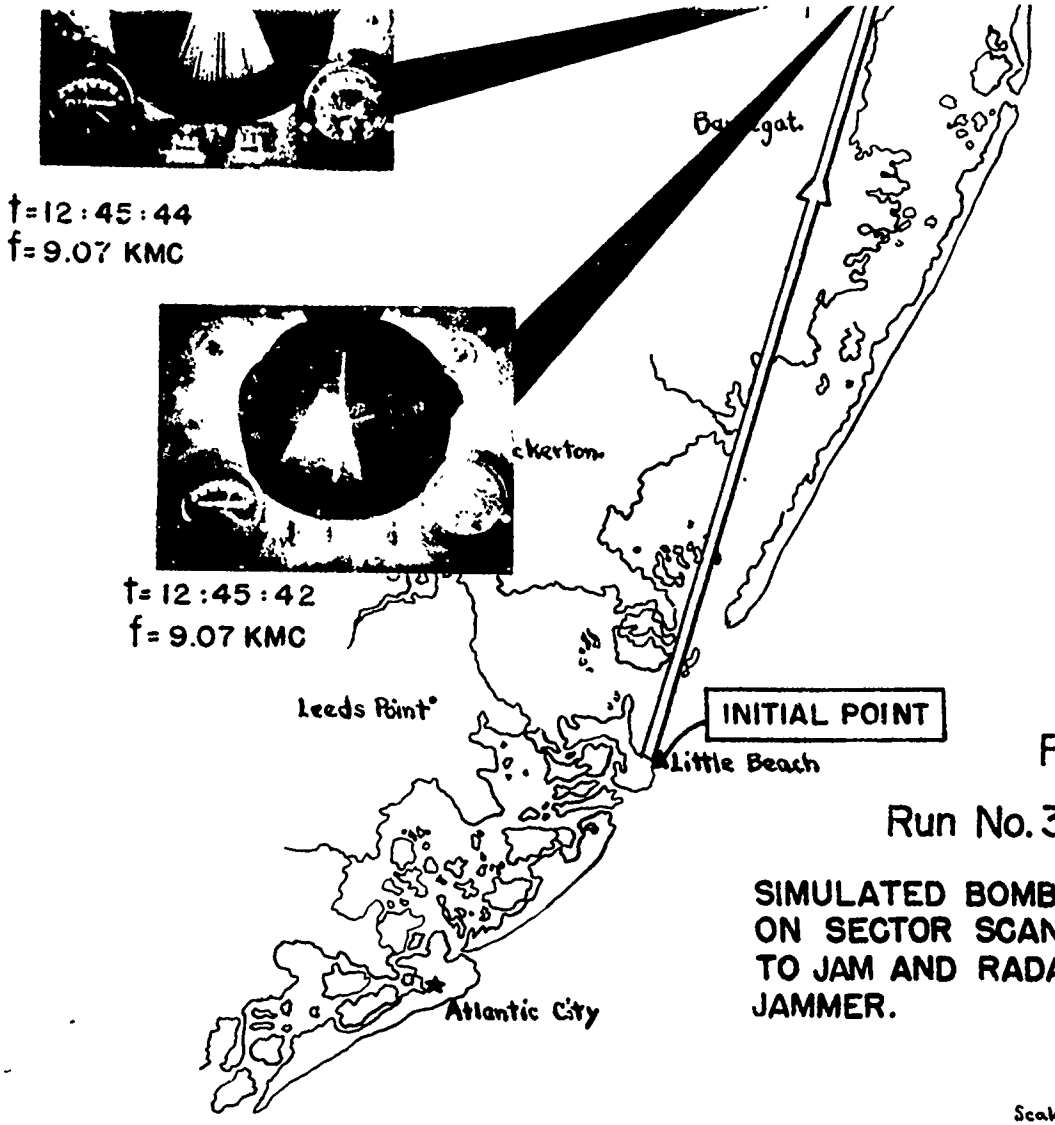


FIGURE 18

Run No. 3, Flight Test No. 3

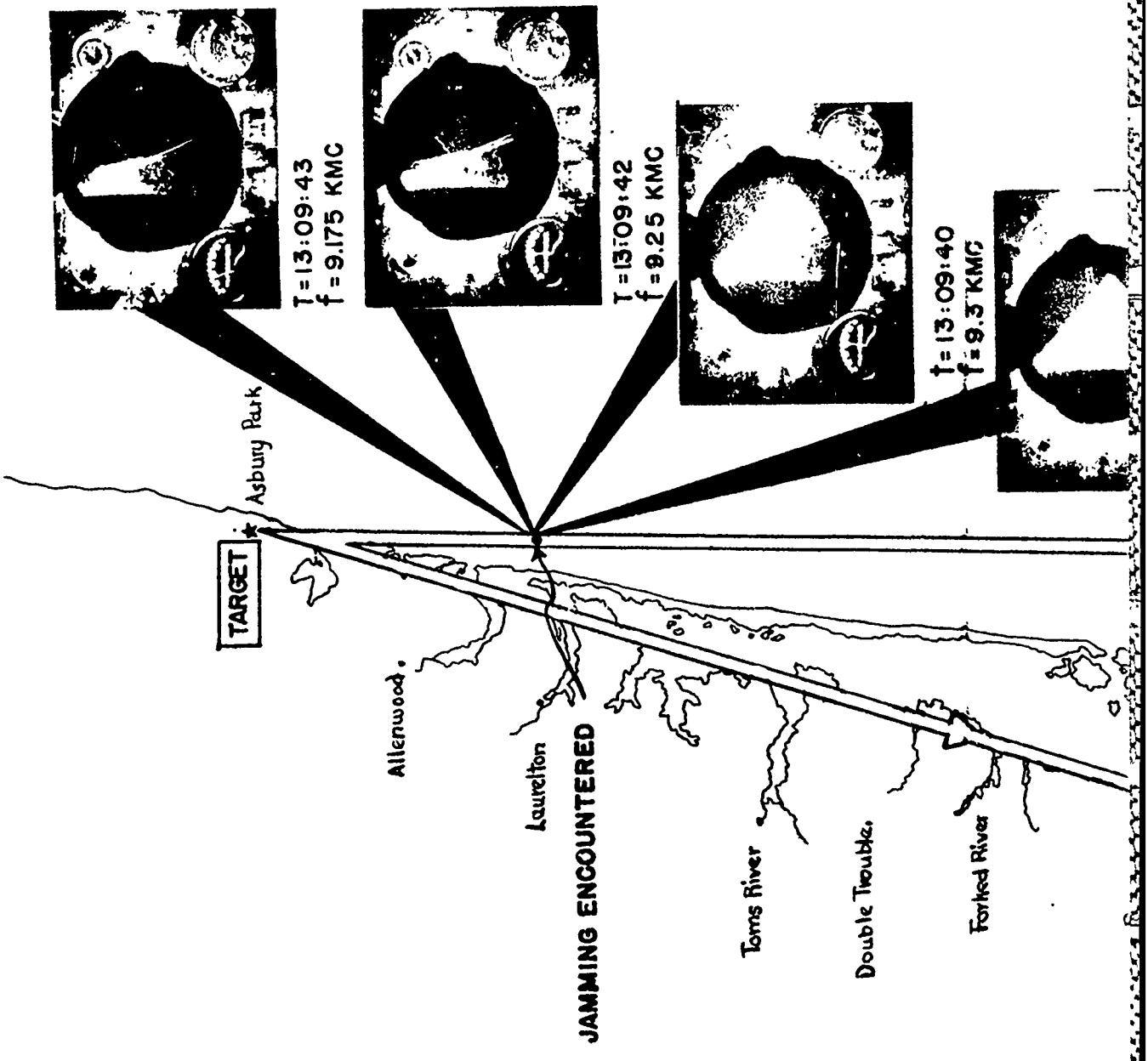
SIMULATED BOMB RUN, RADAR OPERATED ON SECTOR SCAN, JAMMER TRYING TO JAM AND RADAR TUNING TO EVADE JAMMER.

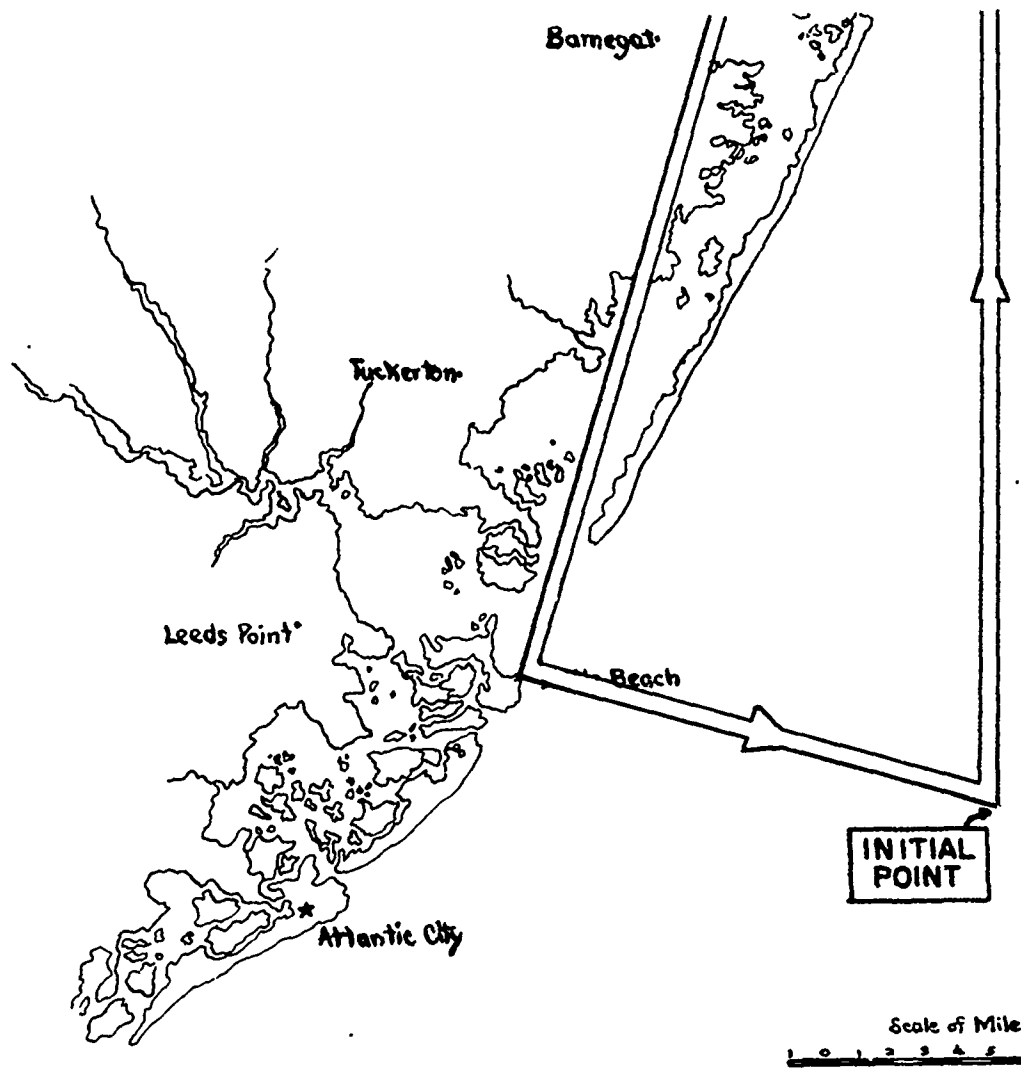
known to the jammer crew. Word was given via radio to the jammer crew when the aircraft was starting its run into the target. The jammer crew had to find the aircraft by search radar (the SCR-584) and then try to effect jamming. During this entire run of approximately 50 miles the jammer was able to jam the radar only once for an instant before the radar operator tuned off frequency. Figure 19 shows the test flight course flown by the aircraft on this run, including radar pictures taken during the run.

Run #5 was conducted in a manner to determine the minimum amount of frequency shift necessary to tune away from jamming with the jammer remaining fixed on one frequency. Tests were made tuning above and below the jammer frequency. Indications showed that by tuning ±35 megacycles about the center of the jamming frequency the radar scope was practically clear of jamming, in many trials ±15 megacycles was sufficient to clear the scope. In some cases the radar was tuned to an extent that left narrow pencil lines of jamming on the scope; however, these lines were not in a position that caused interference on the echo from the target. The jammer was set to approximately 9050 megacycles for this test. Figure 20 shows the course flown on this test run with pictures showing the amount in frequency that the radar operator tuned to evade jamming sufficiently to accomplish a bombing run.

Run #6. The radar operator made tuning jumps of approximately 100 megacycles each time he tuned the radar; the jammer crew was able to jam the radar once during this run. The radar operator pushed the tuning button which immediately cleared the indicator of jamming. Figure 21 shows the course flown on this test run and pictures of the radar screen taken during this run. This run was conducted in the same manner as Run #2, Flight Test 2.

Run #7 was made by the aircraft flying from the jammer site at Evans Signal Laboratory to Reading, Pennsylvania. No radar frequency shift was employed. On this run the jammer frequency remained fixed at 9000 megacycles. Complete jamming of the PPI presentation was observed at a range of 60 miles by the radar operator. At a range of 70 miles the radar operator was able to evade jamming by operation of the antenna tilt control, still without changing frequency. The SCR-584 maintained automatic track of the aircraft for 65,000 yards; from this range to 176,000 yards manual track of the aircraft was maintained. Partial jamming was observed by the radar operator up to a range of 100 miles from the jammer , at which range the SCR-584 lost track of the radar. This completed the tests and the aircraft returned to W-P AFB. No pictures were taken during Run #7, since the camera had used up all the film available on previous runs.

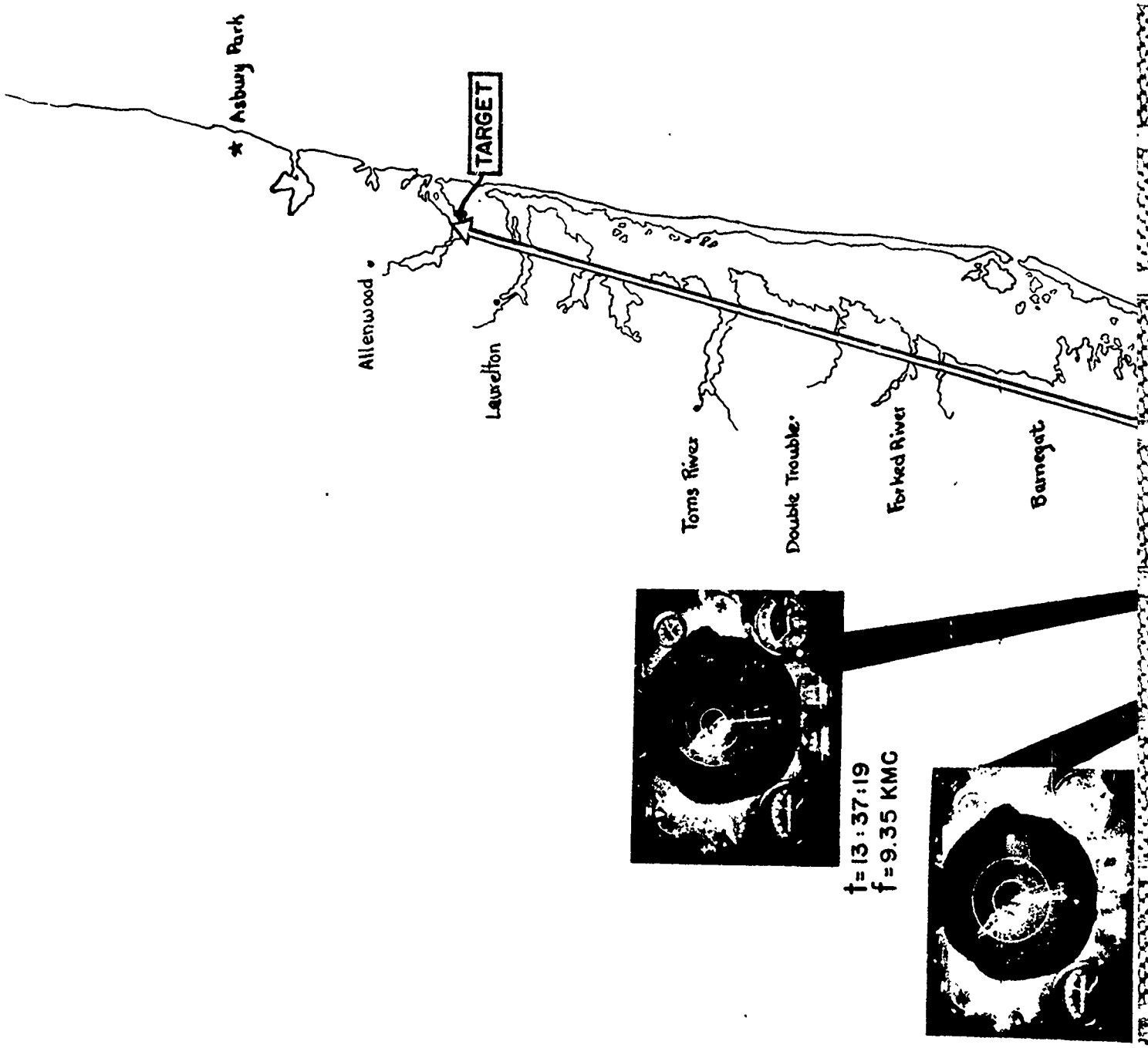

T=13:09:43
f=9.175 KMC
T=13:09:42
f=9.25 KMC
T=13:09:40
f=9.3 KMC
Asbury Park
TARGET
Allenwood
Lakewood
JAMMING ENCOUNTERED
Toms River
Double Trouble
Forked River



t = 13:09:36
f = 9:3 KMC

FIGURE 19
Run No. 4, Test Flight No. 3

EXTREME OPERATIONAL EVASIVE TACTICS WERE USED BY THE RADAR OPERATOR, FALSE TUNING STARTS, SWITCHING TO DUMMY LOAD AND COMING IN TO TARGET FROM AN UNKNOWN HEADING. DURING THIS RUN OF APPROXIMATELY 50 MILES THE JAMMER WAS ABLE TO JAM RADAR MOMENTARILY ONE TIME.


Asbury Park
TARGET
Allenwood
Lakewood
Toms River
Double Trouble
Forked River
Barnegat
t=13:37:19
f=9.35 KMC

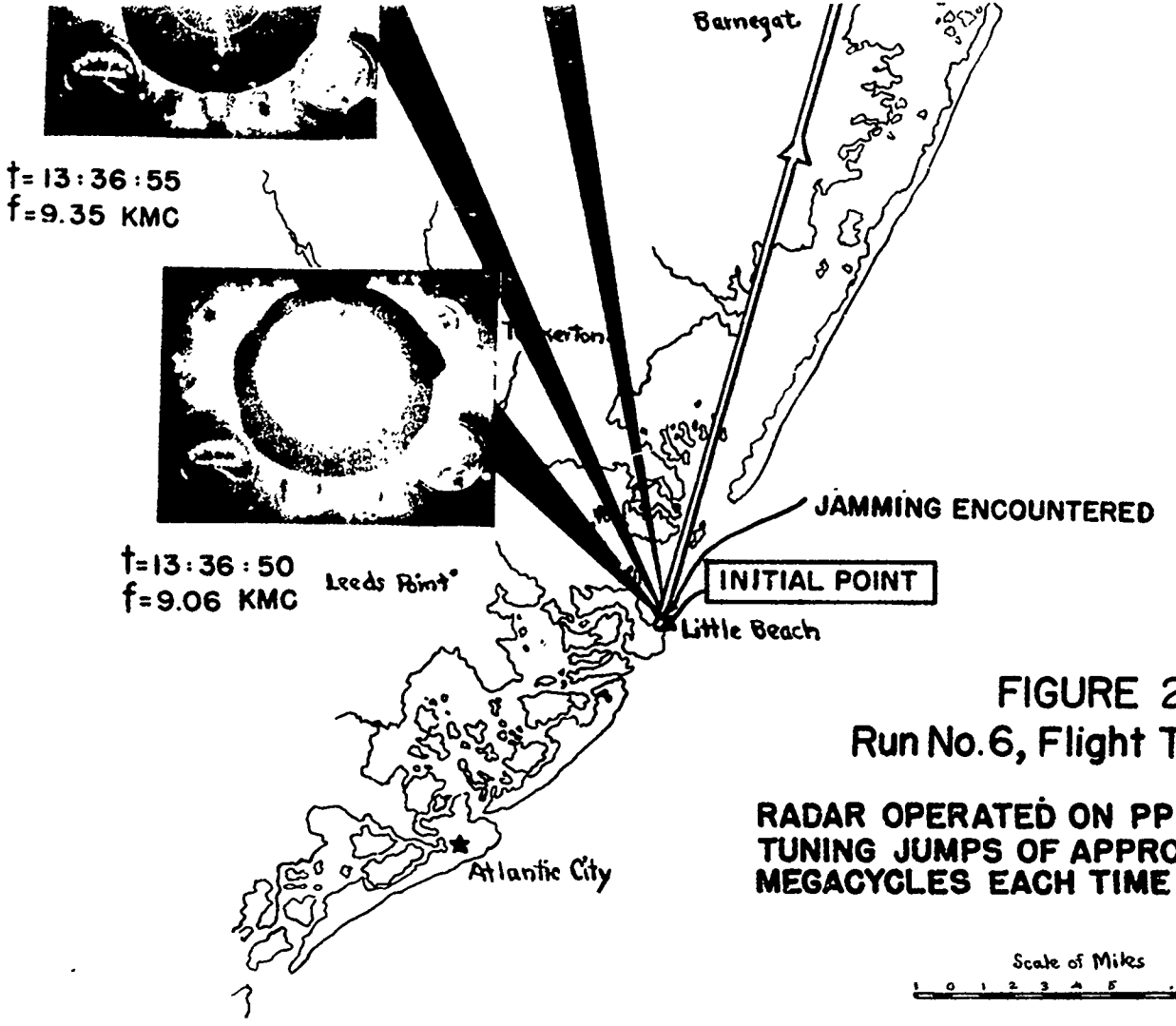


FIGURE 21
Run No. 6, Flight Test No. 3

RADAR OPERATED ON PPI SCAN, MAKING TUNING JUMPS OF APPROXIMATELY 100 MEGACYCLES EACH TIME RADAR IS TUNED.

SECTION II

ANALYSIS OF RESULTS

Based on observations of the project engineer, information obtained from the operating personnel, and the data recorded by the data recording device, the following results were obtained:

1. The radar was not continuously jammed for more than two seconds during any of the test runs where the operator was using all of the evasive tactics possible.

2. The jammer operator could find the radar frequency and set on jamming sufficient to jam the radar momentarily, in from 45 seconds to five minutes. The 45-second figure was the shortest time during the tests in which the jammer operator was able to jam the radar. Only with the use of a plurality of TPQ-8 equipments could this figure be obtained, since continuous look-through is not available with one jammer. The time required to find the radar's frequency and jam was from two to three minutes in most cases. During some of the runs where evasive operations were used by the radar operator, the jammer was only able to jam the radar continuously for two seconds during a bomb run of 20 minutes. In making evasive operational tactics the radar operator used the Sharkey method where he set the computer for automatic steering to the target just before the start of the bombing run. The radar was operated about 30 seconds during each three or four minutes to provide corrections to the computer.

3. The radar operator could continuously observe targets while tuning the radar set when frequency changes not greater than 100 mcs were made. When frequency changes greater than 100 mcs were made, sometimes a period of 10 to 30 seconds elapsed before the AFC reestablished receiver frequency alignment on the new frequency which resulted in no target echoes appearing on the radar scopes for this 10-to-30-second period. This effect is not considered serious, as ways to eliminate this are known and can be incorporated in future airborne tunable radar systems.

4. The operation of tuning the radar over its extreme range, ie., ±500 megacycles, did not cause any observable deterioration of its resolution. A complete report on the resolution tests performed on the AN/APS-23(XA-2) radar is available in a separate WADC Technical Report No. 52-157.

5. The range at which reliable target echoes were obtainable was approximately 50 miles. No attempt was made to increase this range beyond checking the tubes, the crystal, and changing the values of bias resistors. This range is approximately 70% of the normal range obtained from a standard AN/APS-23 Radar Set. No extensive effort was made to increase the range of the AN/APS-23(XA-2), as it was only desired to evaluate the antijamming performance of this low-powered model. Laboratory tests showed that the frequency at which greatest radar range was obtained coincided with that where the system had greatest transmitter output.

6. The tests conducted at 10,000 feet and the tests conducted at 20,000 feet show substantially the same results as far as the antijamming performance is concerned.

SECTION III

CONCLUSIONS

It is concluded from the antijamming evaluation studies and flight tests performed on the AN/APS-23(XA-2) tunable radar set that:

1. The radar could not be effectively jammed by the AN/TPQ-8 jammer.

2. Only one second is required for the radar operator to tune to an unjammed frequency when he encounters jamming from the AN/TPQ-8.

3. With the AN/TPQ-8 sited from 1 to 5 miles of the target, the AN/APS-23(XA-2) operator can accomplish a satisfactory radar bomb run. In performing the bombing run, the radar operator can consistently obtain jam-free operation for one to four minutes time duration for each new frequency setting, which is considered adequate.

4. Tuning the radar ±25 megacycles about the center of the jammer frequency enables the radar operator to clear the indicator of jamming.

5. Tuning the radar often (that is, not waiting until jamming is encountered) results in the jammer signal appearing frequently on the radar indicator. Tuning the radar only when it is jammed by the AN/TPQ-8 results in jamming appearing less frequently on the radar indicator.

6. No observable change of target aspect was apparent to the radar operator because of frequency changes made in operating the radar.

7. Unless notified by radio or unless more than one AN/TPQ-8 is provided for continuous look-through, the jammer operator is not aware that the radar has tuned away from the jammed channel.

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DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

23 June 2010

HAF/IMIO (MDR)
1000 Air Force Pentagon
Washington, DC 20330-1000

Bobby Sammons.
P.O. Box 1680
Cloudcroft, NM 88317-1680

Dear Mr. Sammons

Reference to your letter, undated (attachment 1) requesting a Mandatory Declassification Review (MDR) for Defense Technical Information Center (DTIC) documents:

AD004521	AD005224
AD005736	AD005735
AD006796	AD004876
AD005809	AD003234
AD005808	AD004232

The review for the documents have been completed and the declassification has been downgraded to UNCLASSIFIED and copies are attached for your information.

Address any questions concerning this review to the undersigned at (703) 692-9979 and refer to our case number 07-MDR-076.

Sincerely

JOANNE MCLEAN
Mandatory Declassification Review Specialist

2 Attachments
1. Letter, Request for Documents
2. 10 DTIC Documents

cc: DTIC w/o documents